ARISTOTLE'S RESEARCHES IN NATURAL SCIENCE

THOMAS E. LONES

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ARISTOTLE'S RESEARCHES

IN

NATURAL SCIENCE

BY

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With Illustrative Drawings

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PREFACE.

ARISTOTLE'S researches in Natural Science are set forth in a series of his works, some of which have already received a great deal of attention, while the rest have been much neglected. Translations, with or without explanatory notes, of all these works have been produced in English, French, German, or Latin, and separate treatises or papers discussing Aristotle's researches in one or more branches of Natural Science have been published from time to time. Among such treatises and papers may be mentioned J. Müller's *Über den glatten Hai des Aristoteles, &c.*, Berlin, 1842, a folio volume with six plates, relating, in part, to the placental cartilaginous fishes of Aristotle; J. B. Meyer's *Aristoteles Thierkunde, Ein Beitrag zur Geschichte der Zoologie, Physiologie, und alten Philosophie*, Berlin, 1855; H. Aubert's *Die Cephalopoden des Aristoteles, &c.*, Lepzig, 1862, 39 pp.; C. J. Sundevall's *Die Thierarten des Aristoteles von den Klassen der Säugethiere, Vögel, Reptilien und Insekten*, Stockholm, 1863; G. H. Lewes' *Aristotle: A Chapter from the History of Science*, London, 1864; and Dr. J. Young's paper "On the Malacostraca of Aristotle," published in *The Annals and Magazine of Natural History*, 1865. There are also several works and papers which incidentally give valuable assistance in the study of Aristotle's researches in Natural Science, *e.g.* Cuvier and Valenciennes' *Histoire Naturelle des Poissons*, Paris, 1828–49; J. L. Ideler's *Meteorologia veterum Græcorum et Romanorum*, Berlin, 1832; Spratt and Forbes' *Travels in Lycia, &c.*, London, 1847; Hoffman and Jordan's "Catalogue of the Fishes of Greece, with Notes on the Names now in Use, and those Employed by Classical Authors," published in the *Proceedings of the Academy of Sciences of Philadelphia*, for 1892; D'A. W. Thompson's *Glossary of Greek Birds*, Oxford, 1895; and T. Gill's "Parental Care among Freshwater Fishes," published in the *Annual Report of the Smithsonian Institution*, Washington, 1906.

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A consideration of these and many other similar publications seems to show that a single work, re-examining Aristotle's statements, as far as possible by first-hand investigations, and utilizing the results attained by the above-mentioned and other scholars, would fill a gap in Aristotelian literature. The present work is intended to do this, and represents the nature and value of Aristotle's researches in subjects now considered to belong to physical astronomy, meteorology, physical geography, physics, chemistry, geology, botany, anatomy, physiology, embryology, and zoology. In those parts of the work relating to his anatomical, embryological, and zoological researches, I have tested his statements, whenever possible, by means of actual dissections of the parts of, and observations on, the animals to which he seems to refer.

Throughout this work full references are given to all passages from ancient and modern writers cited. It is hoped that these references will be sufficient to enable the reader to form his own estimate of the statements made or opinions expressed in the course of the work.

As the various Greek texts present differences in method of division as well as in reading, it is necessary to state that the numerous references to Aristotle's works are to the following Greek texts:—Schneider's edition of the *History of Animals*, Aubert and Wimmer's edition of the *Generation of Animals*, the Teubnerian editions of the *Parts of Animals*, *Parva Naturalia*, *De Anima*, *De Cœlo*, and *De Generatione et Corruptione*, and, with very few exceptions, Didot's editions of the remaining works. The references to Aristotelian treatises, *e.g.* the *De Plantis*, not usually considered to have been written by Aristotle, are to Didot's editions.

The abbreviations *H.A.*, *P.A.*, and *G.A.*, have been used frequently to denote Aristotle's *History of Animals*, *Parts of Animals*, and *Generation of Animals*, respectively.

It should be understood that the identifications of animals, attempted in various parts of the work, are not necessarily complete, *e.g.* *Apous* or *Kypsellos* (see p. 245) probably included other birds besides the swift and house-martin, and *Tigris* (see p. 257) included other wild animals besides the tiger of western India. This is evident from passages in Arrian's *Historia Indica*, c. 15, ss. 1 and 3, which read: "Nearchus says that he has seen a tiger's skin, but not a real tiger. . . . and that every one of the

animals which we see and call 'tigers' are jackals, speckled and larger than common jackals."

Except in a few cases, *e.g.* that of the *Hippelaphos*, pp. 253–4, no attempt has been made to consider the possibility of identifying Aristotle's animals with those which may reasonably be assumed to have been unknown to the Ancients.

A few words about the illustrative drawings may not be out of place. Of these, Fig. 3 is of a different kind from the rest. It is drawn according to specific directions given in Aristotle's *Meteorology*, and probably agrees with a drawing forming part of Aristotle's original MS. There are no drawings in the Greek texts, but in many passages there are clear references to drawings.

My thanks are due to Mr. A. R. Wright, Hon. Editor of *Folk-Lore*, for reading the MS. and proof, and for information chiefly relating to popular beliefs recorded by Aristotle; to Mr. F. W. Dunn, B.A., B.Sc., for reading a large part of the MS.; to Mr. F. J. Cheshire, Lecturer in Physics at Birkbeck College, and Mr. R. J. Sowter, B.Sc., for reading all parts of the MS. and proof of Chapters iii. and iv. relating to phenomena of light, heat, and sound; to Mr. F. Gossling, B.Sc., for reading the proof of Chapters v. and vi.; and to my son, Mr. P. E. Lones, for reading those parts of the MS. and proof of Chapters viii.–xiv., relating to human anatomy and physiology.

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CHAPTER I.

INTRODUCTORY.

The Influence of Aristotle's Works.

Among all the works which have come down to us from the Ancients, few have exercised a greater influence on the human mind than those of Aristotle. The nature and extent of this influence have varied greatly during the past two thousand years, but ardent students of the Aristotelian treatises have at all times been found at most of the great seats of learning, and Alexandria, Cordova, Paris, Oxford, Padua, Pisa, and Cologne have been specially distinguished for their Aristotelian studies.

From the very first Aristotle's teaching and writings engaged the attention of scholars, and his method of reasoning and peculiar style of writing were imitated by many of them. At a later time his writings were used as authoritative sources of information by many Greek and Latin authors, and among the many Arabs who studied his writings and did much to preserve them and extend their influence, Avicenna and Averroes may be specially mentioned. After the time of Averroes (1126–1198), Aristotle was followed with implicit confidence until the time of the Reformation.

Before the time of Averroes, however, some of the Aristotelian treatises were read, mainly in consequence of the work of Boëthius, and the Church encouraged the study of such as were useful for training the reasoning powers. The adoption of Aristotle's methods of reasoning was followed by the adoption, in part at least, of his system of philosophy, and the resulting alliance, if it may be so called, between the Church and Aristotelianism became so close that an attack on one was considered to be an attack on the other.

During the early part of the fourteenth century the influence of Aristotle's works appears to have reached its greatest development. That this influence was consider-

able, Dante's writings clearly prove. It is Aristotle to whom he refers when he says:

> "Then when a little more I raised my brow,
> I saw the master of the sapient throng,
> Seated amid the philosophic train.
> Him all admire, all pay him reverence due."*

He also says that Aristotle is most worthy of trust and obedience, for, just as a sword-cutler, bridle-maker, or armourer should obey the knight whose implements he makes, so should we obey and trust Aristotle, who teaches us the end of human life.†

Not long after Dante's time there commenced a great change of attitude towards Aristotelianism, and not only were the Aristotelian writings criticized adversely, but Aristotle's fame, and, above all, his attempts to arrive at the truth, were called in question. After the Revival of Learning this antagonism became very strong. Aristotle and his philosophy, as well as the Church, were attacked by the Reformers, and then by Ramus, Patrizi, and Galileo. In Luther's writings are many passages adverse to the Aristotelian philosophy. He said in one of his debates that he who wished to apply himself, without trial or experiment, to the philosophy of Aristotle, must first become thoroughly inefficient in the School of Christ (*Qui sine periculo volet in Aristotele philosophari, necesse est, ut ante bene stultificetur in Christo*), and asked, in his *Adversus execrabilem Antichristi Bullam*, 1520, why the very wicked philosophy of Aristotle, in which nothing but errors was taught, was not condemned, at least in part (*imo, cur impiissimum Aristotelem, in quo non nisi errores docentur, non saltem in parte damnatis?*). Ramus wrote bitter criticisms of Aristotle's writings. In 1536 he proposed as the title of the thesis for his Degree at Paris: "Everything that Aristotle taught is false." This gave great offence to the Aristotelians, but Ramus sustained the argument so well that he obtained his Degree, and was licensed to teach. His talents were chiefly employed in attacking the Aristotelians, and Ramism replaced Aristotelianism in some of the universities. Patrizi (1529–1597) contended that the works known under Aristotle's name were not authentic, and that the Aristotelian doctrines were false. He also

* *The Vision, Inferno*, Canto iv. (Cary's translation).
† *Il Convivio*, iv. c. 6.

held that Plato and not Aristotle should be considered to be the ally of the Church.

The Aristotelian writings were also assailed by men who worked hard to ascertain facts and test the truth of the Aristotelian philosophy by experiment, when possible. Their attacks happened to be directed against some of the weakest parts of Aristotle's teachings, especially those relating to natural philosophy, and based mainly on abstract reasoning, and, to make matters worse, sometimes misinterpreted by the Aristotelians themselves. Long before the Reformation, Roger Bacon had expressed his contempt for the Aristotelians and their Latin translations of Aristotle's works. Of Aristotle himself, he spoke highly, and at the end of chap. iii. of part 1 of his *Opus Majus*, says that, although Aristotle did not arrive at the end of knowledge, he set in order all parts of philosophy. A much more determined attack was made after the Reformation by Galileo, Lord Bacon, and other experimentalists. One very direct attack by Galileo is of more than ordinary interest. In his *Physics*, iv. c. 8, s. 8, Aristotle says that when bodies fall through various media the rate of falling depends on: (1) the nature of the medium, (2) the weights of the falling bodies, other things being equal. He then deals with these determining causes, and, although his reasoning is sometimes obscure and occasionally inconsistent, it is evident that he considered the velocity of a falling body to be proportional to its weight. The Aristotelians at Pisa strenuously supported this view, and, unable to convince them of error by argument, Galileo resorted to experiment. He ascended the leaning tower of Pisa, and showed that bodies of different weights, dropped together from a convenient part of the tower, struck the ground simultaneously. He is said to have used two shot, one ten times heavier than the other. Notwithstanding this experiment, the Aristotelians still argued against Galileo, and would not abandon their opinion that the velocity of a falling body was proportional to its weight. They were greatly incensed against Galileo, and in 1591 he found it advisable to resign his professorship at Pisa. The way in which the Aristotelians at Pisa defended what they believed to be the views of their master is a striking proof of the great influence of Aristotle's writings, even as late as the end of the sixteenth century.

Lord Bacon made caustic comments on Aristotle, and

held his followers in contempt. It has been said that Lord Bacon knew little of Aristotle's works first-hand, but this was a common fault among the scholars of his time. He said that no weight should be given to the fact that Aristotle, in some of his works, deals with experiments, for he had formed his conclusions before, and made experiments conform with what he wished;* and, commenting on the fewness of the authors referred to in Aristotle's works, Lord Bacon said that Aristotle, on whom the philosophy of his day chiefly depended, never mentioned an author except to confute and reprove him.† The chief effects of Lord Bacon's antagonism, however, were ultimately seen in the replacement, to a large extent, of the Aristotelian philosophy by the "New or Experimental Philosophy," expounded chiefly in the *Novum Organum*.

The Aristotelians facilitated the success of their opponents by their own excessive zeal. They adopted, to a greater extent than Aristotle did, the Platonic ideas about the supreme importance of abstract speculation, and the intellectual degradation associated with the work of artizans and others who provide for the common wants of mankind; they neglected Aristotle's advice to make sure of the facts before trying to explain the causes; they often put a forced construction on Aristotle's words; they went too far in their attempts to show that Aristotle was infallible. Their position was difficult in the fifteenth century, when the Revival of Learning was in progress, accompanied by a great increase in commercial prosperity and the growth of affluence and power among the very classes whom they pretended to despise. In later times, when they were opposed by men who were both scholars and experimentalists, their position became almost untenable. The interest taken in Aristotle's works became less and less until, during the first half of the eighteenth century, most of his writings were very much neglected.

It is interesting to find that, during this period of comparative neglect of the study of Aristotle, the interest taken in his zoological works became greater perhaps than it had ever been. Conrad Gesner, Belon of Le Mans, Rondelet, and others wrote large treatises, much of the groundwork of which was obtained from Aristotle, and

* *Novum Organum, Aphorism* 63.
† *Filum Labyrinthi*, &c., part i. § 8.

Francis Willughby, John Ray, and Peter Artedi (whose work on ichthyology was edited by Linnæus) were students of Aristotle. Gesner's *Historia Animalium*, 1551–87, containing numerous extracts from and comments on Aristotle's *History of Animals*, was the standard work on animals for many years.

In the latter part of the eighteenth and early part of the nineteenth century there was a revival of interest in Aristotle's writings. This revival, effected to a large extent by the efforts of Lessing and Hegel, has not died out. On the contrary, the interest taken in Aristotle's writings has been steadily increasing, and the peculiar character of these writings will probably cause such interest to increase still more, for they represent more fully than any others the highest intellectual development of ancient Greece. The opinions of the philosophers who preceded him are more fully and accurately set forth by Aristotle than by any other writer. He gives valuable accounts of their views, and discusses how far they should be accepted or rejected. He also makes extensive additions to the knowledge obtained from his predecessors, and adds the results of his own researches in many subjects which they had never investigated. It may be fairly claimed that, in his attempts to separate and define the various branches of learning, Aristotle established several new sciences, more especially Logic, Rhetoric, Ethics, and Zoology. The best parts of his writings on these subjects have passed into modern treatises. Large parts of his Analytics have been absorbed in this way. Little has been added by later writers to his work on rhetoric. In modern zoological works, excepting most of those describing the results of recent researches, or animals unknown to Aristotle, many statements are made which recall to the mind of the Aristotelian scholar passages in the *History of Animals* or other Aristotelian treatise. It has also been contended, not always groundlessly, that some passages in Aristotle's works anticipated several theories and discoveries of modern times. Among such alleged anticipations may be mentioned the undulatory theory of light, the so-called law of organic equivalents, the hectocotylus of certain cephalopods, the nest-making habits of some fishes, and the occurrence of hermaphroditism in some species of *Serranus*.

The unobtrusive, even hidden, influence of the Aristotelian writings is perhaps more striking. This influence is

to be traced in the most unexpected connections. Sir Alexander Grant tells us that the passages in Aristotle's *De Cœlo*, ii. c. 14, 298*a*, in which he inclines to a belief that the ocean to the west of Europe and that to the east of India are one and the same, did much to influence the mind of Columbus and send him on his memorable voyage, and that they were the cause of the islands of Central America being called the West Indies, and the aborigines of North America being called Indians. Further, there are many words and phrases which have become firmly established, although with modified meanings, chiefly through the influence of the Aristotelian writings. Among these words and phrases may be mentioned the following:—

aorta	essence	motive
category	faculty	natural history
cetacea	final cause	physician
coleoptera	form	predicament
diptera	habit	principle
energy	malacostraca	quintessence
entelechy	maxim	selachia
enthymeme	mean between extremes	syllogism
entomology	metaphysics	

The well-known saying, "There is nothing new under the sun," is several times given by Aristotle, in equivalent language, *e. g.* in his *Meteorol.* i. c. 3, s. 4, he says that the same ideas have recurred to men times without end; and, in his *Polit.* vii. c. 9, 1329*b*, he expresses his belief that discoveries and inventions come easily to men, and have been made over and over again by different peoples and in different countries.

The foregoing is but an outline to indicate the vast extent to which Aristotle's writings have exercised the minds and influenced the conduct of men in many countries and in almost every age for more than two thousand years. He has had many adverse critics, but many more followers or admirers possessed with an enthusiasm for his philosophy which has often been nearly as great as that shown by the Aristotelian, Thomas Aquinas. Many of them have written commentaries on some parts of his works, especially his *Ethics*, *Politics*, *Metaphysics*, *De Anima*, and parts of his *Organon*, and so vast is the Aristotelian literature that no man can hope to attain more than a general knowledge of it.

Life and Character of Aristotle.

Aristotle was born, probably in B.C. 384, at Stagira, a Greek colony near the Strymonic Gulf, and about seventy miles eastward from Pella, the capital of Macedonia. His father, Nicomachus, was physician-in-ordinary to Amyntas II., King of Macedonia. After the death of Nicomachus, Aristotle went to Athens, where he became a pupil of Plato; this important step was taken, it is generally believed, when Aristotle was seventeen years old. Plato soon formed a high opinion of Aristotle's abilities, and called him "the intellect of his school." While he was with Plato he began a controversy against Isocrates, the distinguished rhetorician, and it is said that Aristotle went so far as to open a school of rhetoric in opposition to Isocrates.

Soon after Plato's death, B.C. 347, Aristotle left Athens and went to Atarneus, in Mysia, where he resided with his friend Hermias, despot of Atarneus, whose niece, Pythias, he married. In B.C. 344 Hermias was treacherously captured by the Persians and put to death. It was then unsafe for Aristotle to remain at Atarneus, so he escaped to Mitylene.

In B.C. 342, at the request of Philip of Macedon, he became tutor to Philip's son, Alexander. In consequence of this Aristotle lived in Macedonia for seven years, and was greatly honoured. One favour granted to him was of so regal a character as to deserve special mention. His native town had been destroyed by Philip during the Olynthian War, B.C. 350–47, and its inhabitants slain or dispersed. After a request by Aristotle, Philip gave express orders that Stagira should be rebuilt, and its inhabitants reinstated as far as possible.

At the death of Philip, B.C. 336, Alexander became King of Macedonia, and soon afterwards completed his preparations for the invasion of Asia. Before Alexander proceeded on his career of conquest Aristotle went to Athens, where the Lyceum was assigned to him by the State. Here he established his famous School, afterwards called the Peripatetic.

Aristotle appears to have produced most of his works during the time, B.C. 335–23, when he was at the Lyceum. His reputation as a philosopher was high, and, as a friend of Alexander and his viceroy Antipater, his influence must have been great. Among his pupils were the well-known

Theophrastus, Eudemus of Rhodes (who is believed to have written the *Eudemian Ethics*, and some other Aristotelian treatises), and Cassander, son of Antipater.

It has been asserted that Alexander placed at Aristotle's disposal several thousand men to make collections of all kinds of animals for Aristotle's own use, and that, with the aid of materials thus provided, his renowned work, the *History of Animals*, was produced.* The truth of this story has been doubted, partly because Macedonia was a poor country and could not bear the expense which the collection of a vast number of animals would necessitate. This, however, is not a valid objection, for although Macedonia itself was poor, Alexander obtained vast stores of wealth during his campaigns in Asia. Athenæus tells us that, according to rumour, Aristotle received eight hundred talents from Alexander to enable him to finish his *History of Animals*.† A passage from Ælian makes the truth of the matter doubtful. He says that Aristotle produced his *History of Animals* with the aid of the wealth of Philip, and that Philip honoured Plato and Theophrastus.‡ The whole question of the supposed aid rendered to Aristotle by Philip or Alexander, or both, is involved in obscurity. Having regard for the undoubted facts that Philip esteemed Aristotle very highly, and that Alexander was very friendly towards him while he was his pupil and for some years afterwards, it is clear that Aristotle could have obtained assistance from them. It is less likely that such assistance was given in later years, because Alexander's feelings towards him cooled by degrees, and were perhaps somewhat hostile after the arrest, on a charge of conspiracy, of Callisthenes, who was a pupil and nominee of Aristotle serving with Alexander in Asia.

After Alexander's death, B.C. 323, Aristotle was watched with suspicion at Athens, for he was considered to be friendly to the Macedonian power, and he also had many enemies among the followers of Plato and Isocrates. Further, an incident which could not fail to give great offence to the Athenians and other Hellenes had occurred in B.C. 324. At the Olympic festival in that year, Alexander caused a proclamation to be made that all Greek cities should recall all exiles who had been banished by judicial sentence. The officer who made this proclamation was

* Pliny, *Nat. Hist.* viii. 17. † *Deipn.* ix. 58.
‡ *Variæ Historiæ*, iv. 19.

Nicanor, friend of Aristotle and son of Proxenus, who had been Aristotle's guardian. On account of his close connection with Nicanor, who afterwards became his son-in-law, Aristotle shared in the odium caused by this event.

While Alexander lived, Aristotle was practically safe from the attacks of his enemies, but, as soon as it was known that the great conqueror had died, Aristotle's enemies sought to ruin him. He had not taken an active part in Athenian politics, for he was not a citizen of Athens, and his enemies, not being able to bring a political charge against him, determined to accuse him of impiety. He had written a poem in honour of Hermias, associating his name with the names of the greatest heroes of Hellas, and he had erected a statue of Hermias at Delphi, with an inscription in his honour. These were the chief charges against Aristotle, the Athenians considering that it was especially impious to praise Hermias as if he had been a demi-god. These specific charges were supplemented by references to passages in Aristotle's works tending to show his impiety. A modern reader would have some difficulty in finding passages of this nature, but it should be remembered that the Athenians gave a very wide meaning to that impiety, at which they expressed great horror. They found some passages, so it is said, suitable for supporting their prosecution, such as, for example, certain statements to the effect that prayer and sacrifices to the gods were of no avail.

During the short time between Alexander's death and the preferring of the charges against Aristotle, the anti-Macedonian party became more powerful, and Aristotle soon felt that he would be unable to withstand the attacks of his enemies. He availed himself of an Athenian law which allowed an accused person to avoid the risk of a trial by going into voluntary exile, and escaped to Chalcis, in Eubœa. Shortly afterwards he died a natural death, at Chalcis, in B.C. 322, at the age of about sixty-two years. Diogenes Laërtius, in his Life of Aristotle, says that he died through taking poison, but there does not appear to be any reliable evidence for this assertion.

From statements made by various ancient writers, we learn that Aristotle was rather short and slim; that his eyes were small and his speech lisping; that he was vivacious and energetic, although his bodily constitution was weak; and that he lived very elegantly and paid great attention to his dress and personal appearance.

Possessed of considerable means, enjoying the friendship of the most powerful rulers of his time, occupying a high social position, and having great opportunities for prosecuting his investigations, Aristotle was the most fortunate of philosophers. He appears to have lived a highly honourable life, and no charge indicating any serious defect of character seems to have been proved against him. Many passages in his works are indicative of high moral feeling. Of his religious beliefs we know very little. When he refers to the gods, or Hellenic beliefs, he does so reverently, but these subjects appear to have been avoided by him. Although his views on the subject are not sufficiently clearly expressed, he does not seem to have believed in the immortality of the soul of an individual. According to him, all parts of the soul, except perhaps the intellectual soul, are inseparable from the body.* Man and other animals cannot participate in immortality, yet each individual tries, one more and another less, to participate in a kind of immortality by producing individuals like itself, all being members of an everlasting species.†

Antipater testifies to the effect that Aristotle was courteous and persuasive in manner. That he was kind and considerate is shown by the way in which he drew up his will, as it is given by Diogenes Laërtius, carefully providing for his second wife Herpyllis, his daughter Pythias, his son Nicomachus, and his slaves. He made provision for some of his slaves, and expressly willed that none of his young slaves should be sold.

After his death there were many detractors of his reputation. Ælian states that Aristotle squandered his paternal fortune, then served in the army, and, failing there, became a seller of drugs.‡ One of the characters in Athenæus says that he could narrate a great deal about the nonsense which the seller of drugs talked, and then gives statements about Aristotle agreeing with those cited above from Ælian, but adds significantly that Epicurus alone spoke thus of him, for, although Eubulides and Cephisodorus wrote books against him, neither ventured to assert anything of this kind.§ Grote tells us that Epicurus was not the only witness, for the same statements were made by Timæus. Other charges were made against Aristotle, but

* *De Anima*, ii. c. 1, 413*a*; ii. c. 2, 413*b*.
† *Ibid.* ii. c. 4, 415*b*.
‡ *Variæ Historiæ*, v. 9. § *Deipn.* viii. 50.

the mere statement of many of these, such as that accusing him of aiding in poisoning Alexander, constitutes the most effective refutation of them. The charge of aiding in poisoning Alexander is mentioned by Pliny,* but it should be mentioned, in justice to Pliny, that he himself was a great admirer of Aristotle, and that he adds that the charge was false and did great injustice to him. It can scarcely be denied that Alexander died a natural death at Babylon.

Aristotle's Writings on Natural Science.

Of the numerous works which have been included among the Aristotelian treatises, there are some which are considered to have been written, not by Aristotle but by his pupils or followers. The determination of Aristotle's own works has engaged the attention of many scholars, and has been very difficult. This question has been considered from almost every conceivable point of view, and, as regards those works dealing with subjects which may be said to belong to the Natural Sciences, it is now generally believed that those mentioned below are genuine works of Aristotle. The Greek titles and their usual Latin and English equivalents are given in each case.

(1) φυσικὴ ἀκρόασις, *Auscultatio Naturalis*, 'Physics.'

(2) περὶ οὐρανοῦ, *De Cœlo*, 'On the Heavens.'

(3) περὶ γενέσεως καὶ φθορᾶς, *De Generatione et Corruptione*, 'On Generation and Destruction.'

(4) μετεωρολογικά, *Meteorica*, 'Meteorology.'

(5) περὶ ζώων ἱστορία, *De Animalibus Historia*, 'History of Animals.'

(6) περὶ ζώων μορίων, *De Animalium Partibus*, 'On the Parts of Animals.'

(7) περὶ ζώων πορείας, *De Animalium Incessu*, 'On the Progressive Motion of Animals.'

(8) περὶ ψυχῆς, *De Anima*, 'On the "Soul" or the Vital Principle.'

(9) περὶ ἀναπνοῆς, *De Respiratione*, 'On Respiration.'

(10) περὶ αἰσθήσεως καὶ αἰσθητῶν, *De Sensu et Sensibilibus*, 'On Sense and Objects of Sensation.'

(11) περὶ ζωῆς καὶ θανάτου, *De Vita et Morte*, 'On Life and Death.'

(12) περὶ μνήμης καὶ ἀναμνήσεως, *De Memoria et Reminiscentia*, 'On Memory and Reminiscence.'

* *Nat. Hist.* xxx. 53.

(13) περὶ ὕπνου καὶ ἐγρηγόρσεως, *De Somno et Vigilia*, 'On Sleep and Wakefulness.'

(14) περὶ ἐνυπνίων, *De Insomniis*, 'On Dreams.'

(15) περὶ μακροβιότητος καὶ βραχυβιότητος, *De Vitæ Longitudine et Brevitate*, 'On Length and Shortness of Life.'

(16) περὶ νεότητος καὶ γήρως, *De Juventu et Senectute*, 'On Youth and Old Age.'

(17) περὶ ζώων γενέσεως, *De Animalium Generatione*, 'On Generation of Animals.'

Nos. 9 to 16, both inclusive, form the chief parts of the so-called *Parva Naturalia*.

The following are considered to be spurious, or at least doubtful :—

(1) περὶ ζώων κινήσεως, *De Animalium Motione*, 'On the Motion of Animals.'

(2) περὶ κόσμου, *De Mundo*, 'On the Universe.'

(3) περὶ χρωμάτων, *De Coloribus*, 'On Colours.'

(4) περὶ φυτῶν, *De Plantis*, 'On Plants.'

(5) τὰ προβλήματα, *Problemata*, 'The Problems.'

Aristotle's works, as a whole, are characterized by relevancy and methodical arrangement of subject-matter, conciseness of expression, and simplicity of language. Many parts of his *History of Animals*, *Meteorology*, *Parts of Animals*, *Respiration*, *Progressive Motion of Animals*, and *Generation of Animals*, illustrate these characteristics. They clearly show his desire to state facts, or his own opinions, in a plain way, there being but few attempts to write in a highly polished style.

The subject-matter of his works varies considerably in interest. Many parts of the works referred to above furnish very interesting reading, but some parts of his works are of very little interest and even tedious, such as, for example, many parts of Books iii. and iv. of his work on the *Heavens* and Books iv. v. and vi. of the *Physics*. In his *Aristotle*, &c., 1864, p. 143, G. H. Lewes expresses an opinion that Aristotle's *Generation and Destruction* is in his most wearisome style of verbal disputation. It may be said, however, that some parts of this work are very interesting, especially the numerous passages in which Aristotle gives his views on mixture, and what may be fairly called chemical composition. Some passages of his works, even where the subject-matter is simple, *e. g.*, those in *H. A.* ii. c. 2, s. 6, relating to the way in which the feet of camels are divided,

are very difficult to translate or understand, but, in most cases, the difficulties are chiefly due to the abstruse nature of the subjects to which the passages relate.

Aristotle often sets forth what he intends to discuss, and the order in which he proposes to discuss the various branches of a subject, and he often gives a valuable description and criticism of the views of other philosophers on the subject under discussion.

Numerous instances might be given of the pertinence of his style, *e. g.*, cc. 1–12 of his work on *Respiration*, his description of the arrangement of the blood-vessels, in his *History of Animals*, iii. cc. 2–4, his descriptions of four of his groups of animals, the *Malakia*, *Malakostraka*, *Ostrakoderma*, and *Entoma*, in his *History of Animals*, iv. cc. 1–7, his descriptions of many separate animals, *e. g.*, the Chamæleon, the Cuckoo, the Elephant, and the Barbary Ape, in various parts of his *History of Animals*, and his description of rainbows, primary and secondary, in his *Meteorology*, iii. c. 2, ss. 3–5. The reader is sometimes checked by suddenly coming upon a passage which has little or no apparent connection with what precedes it, but some passages of this kind are interpolations, and may be commentators' marginal notes which have found their way into the texts. The apparent interpolations are rarely of any value, and are often inaccurate.

Generally speaking, Aristotle's method of treating a subject is very different from Plato's. There is certainly much abstract reasoning in some of his works, but this is avoided in his *History of Animals*, in many parts of his other zoological works, and in many parts of his *Meteorology*, which contain records of a vast number of interesting phenomena and facts. He is eminently practical, and is the first to condescend to regard the observation of things themselves as an important part of the foundation of knowledge. In some cases, where he could not or did not observe for himself, he seems to have relied on the statements of hunters, fishermen, and others. As might be expected, some of his worst errors resulted from his adoption of these statements.

Many words, some of which were recognized Greek words before his time, are employed by Aristotle in a special sense. Most of his assertions are made in short, simple sentences, and ellipses often occur. There are also repetitions of many statements in the same or slightly

different language, *e. g.*, he tells us that his *Selache* are cartilaginous, or that they are ovoviviparous, in many different passages, most of his statements about his homœomeria in the *History of Animals* are repeated in his *Parts of Animals*, and many parts of the subject-matter of his *Generation and Destruction* are to be found in his remaining works.

In his zoological works are many passages which the context does not explain, and quite one-half of the animals mentioned by him are not described in such a way as to enable them to be identified. The reason for this is that in many cases the animals are mentioned merely for the purpose of illustrating general statements. On the other hand, several passages which are not explained by their contexts are made clear in one or more passages of the same or a different work, *e. g.*, that in his *History of Animals*, i. c. 5, s. 7, which asserts that animals walk κατὰ διάμετρον, is fully explained in his *Progression of Animals*, c. 14. It is necessary, in fact, to study many passages in several of his treatises, in order to understand his views on most scientific subjects, and, it should be mentioned, some of these passages are not consistent. Two works, the *Zoica* and *Anatomica*, to which he sometimes refers, would have thrown light on difficult passages in his extant zoological works. Those two works, however, have not been recovered.

It has often been stated that in his zoological works Aristotle has borrowed from many writers without acknowledgment. This charge seems to be substantially true, although he specifically mentions Anaxagoras, Empedocles, Democritus of Abdera, Alcmæon, Dionysius of Apollonia, Herodotus, Syennesis of Cyprus, Polybus, and a few others. The comment made by Cuvier and Valenciennes, when speaking of Aristotle's work in connection with fishes, is not unfair. They say: "It is true that, by a practice only too common in our own time, Aristotle scarcely mentions other authors, except those whom he wishes to refute, and he has been charged even with ingratitude to Hippocrates, whose name he does not mention, although he must have borrowed from him more than one idea. As regards the rest, we do not think that he has done much wrong to the ichthyologists, if any, who preceded him. The fragments preserved by Athenæus, which we can attribute to them, do not show that they treated their subject methodically or carefully, and everything makes us believe that it was

through Aristotle's writings only that ichthyology, like all other branches of zoology, first took the form of a science."*

Eubulides and others charged Aristotle with ingratitude to Plato. This charge has been much discussed by modern writers, and in connection with it it may be said that in Aristotle's zoological works there are passages which, like the one in his *History of Animals*, iii. c. 3, s. 2, about the heart being the origin of the blood-vessels, look like developments of statements found in Plato. Aristotle is deserving of censure for not acknowledging Plato, if he was indebted to him for the groundwork of such passages. To decide whether this was so seems to be impossible, for, independently of arguments which might be adduced for settling it, the question is complicated by the fact that for some years Aristotle was Plato's most gifted pupil, and the imparting of ideas may not always have been from tutor to pupil. In matters connected with the nature and arrangement of the parts of animals Plato may have been somewhat indebted to Aristotle.

The Order of Aristotle's Works dealing with Natural Science.

Much labour has been spent by Aristotelian scholars in trying to determine the relative positions of Aristotle's works, and a consideration of some of the views held on this subject may be of interest. Not only is the evidence on which the inquiry rests of such a nature that it is difficult to estimate its true value, but the inquiry itself is complicated by the probability that Aristotle had more than one work on hand at one and the same time.

It is usually considered that Aristotle's *Physics*, *Heavens*, *Generation and Destruction*, and *Meteorology*, were written before the zoological treatises, including the *De Anima*, and that these were begun soon after the *Meteorology*. There are, in fact, some apparently genuine passages in the *Meteorology* which strongly support this view. The *Physics* was probably written before the *Heavens* which, it has been computed from the description of an occultation of Mars in Book ii. c. 12, 292*a* of that work, was written after B.C. 357. There is also a passage in *Meteorol.* iii. c. 2, s. 9, which suggests that the *Meteorology* was not completed before B.C. 334, for Aristotle there says that he had known of only two instances of lunar rainbows during a period of over fifty years.

* *Hist. Nat. des Poissons*, Paris, 1828–49, vol. i. pp. 15–16.

The difficulty of deciding on the probable order of the zoological works, including the *De Anima*, has been much greater than that of deciding on the probable order of the *Physics*, *Heavens*, *Generation and Destruction*, and *Meteorology*, and the difficulty was not lessened by Titze's suggestion, in 1826, that Book i. of the *Parts of Animals* was originally an introduction to the *History of Animals*. It is generally admitted that the *De Anima* comes early in Aristotle's series of zoological and related works, and, so it seems from the last sentence of the *Progressive Motion of Animals*, immediately after this last-named work. It is also generally admitted that the *Parva Naturalia* come after the *De Anima*.

With respect to the probable order of the three important works, the *History of Animals*, *Parts of Animals*, and *Generation of Animals*, it will be well to give the views of some Aristotelian scholars. Furlanus of Crete believed that the *History of Animals* should precede all the other works by Aristotle on animals.* Schneider concluded that the order was *History of Animals*, *Parts of Animals*, and *Generation of Animals*. Prantl, in his *De Aristot. Libr. . . . Ordine atque Dispos.*, &c., Munich, 1843, p. 28, and Titze, in his *De Aristot. Operum Serie*, &c., Leipzig and Prague, 1826, pp. 58 *et seq.*, adopted a similar order for these three works. Valentin Rose also adopted a similar order, and was inclined to believe that the *History of Animals* was probably written some years after the battle of Arbela, B.C. 331, or very likely after the return of the veterans of Alexander's army, say B.C. 326, or not before B.C. 327, mainly on the ground that the elephants, about which Aristotle had information, were those taken in war by the Macedonians.† On the other hand, some have held that the *Parts of Animals* should come first. Patrizi says: "I know that all Aristotelians contend that the *History of Animals* should precede all the other zoological works, because they think that the phenomena are prior to and better known than their causes, and that we should begin with what is better known." ‡ Again, he expresses an opinion that the *History of Animals* should be put in the last place, and that all who had put

* In *Libr. Aristot. de Part. Anim. Comment. primus*, &c. Venice, 1574. Preface, p. 11.

† *De Aristot. Libr. Ordine et Auctor. Comment.* Berlin, 1854, pp. 216, 240, and 241.

‡ *Discuss. Peripat.*, &c. Venice, 1571, p. 79*a*.

it in the first place had inverted the order of Aristotelian philosophy.* Sir A. Grant says that the *Parts of Animals* may very likely have been written first after the *Meteorology*.† Another question, to which reference has been made, should now be considered. Book i. of the *History of Animals* has no well-marked Introduction, and the commencement is so abrupt, compared with the opening parts of Aristotle's other works, that many commentators have believed that the *History of Animals* once had an Introduction which has been lost or transposed. Patrizi seems to have believed that the *Parts of Animals* should be regarded as an Introduction to the entire series of Aristotle's zoological works. Titze argued that Book i. of the *Parts of Animals* was originally the Introduction to the *History of Animals*; that some transcribers so regarded it; and that some ignorant or careless critic, losing sight of the fact that it was an Introduction to the *History of Animals*, transferred it and ordered it to be made the first book of the *Parts of Animals*.‡ This suggestion has not met with general approval, but it was adopted by Dr. von Frantzius, editor of our best Greek text of the *Parts of Animals*, and by Carl J. Sundevall, the author of a well-known work on some of the animals mentioned by Aristotle.

The most profitable way of dealing with the question of the probable order of the chief zoological works seems to be to consider not only the order of production or publication, but also the order in which these works should come in Aristotle's system, or the order in which he intended them to be studied.

There are many passages in the zoological works stating that certain subjects have been discussed, or will be discussed, in other works, the titles of which are clearly indicated, *e.g.*, in *P. A.* iii. c. 14, 674*b*, it is stated that the relative positions and shapes of the parts of the stomach of a ruminant should be ascertained from the *History of Animals*. Passages such as the last-mentioned, assuming them to be genuine, show that the *History of Animals* preceded most, if not all, of the other zoological works. Some commentators who have found leisure to examine the references thoroughly have concluded, however, that a few

* *Discuss. Peripat.* &c. Basle, 1581, p. 123.

† *Aristotle.* Edinburgh and London, 1877, p. 47.

‡ *De Aristot. Operum Serie et Distinctione.* Leipzig and Prague, 1826, p. 55.

of them are inconsistent, and that many, if not all, have been inserted by editors and others. Still, the value of these references as evidence is not negligible, and a careful search through the zoological works does not reveal any passage in which the *History of Animals* is referred to as a work in contemplation. Then there are references and indications which are more closely bound up with the contexts and are undoubtedly genuine parts of Aristotle's works. In his *Analyt. Prior.* i. c. 30, it is said that the facts relating to a subject should be ascertained before an attempt is made to reason about it. He also proposes to consider the "causes" and generation when the animals and their peculiar features have been described.* The term "causes" is used in a special sense for those on account of which the parts of animals are composed and arranged in the manner described in the *History of Animals*,† and most of the *Parts of Animals* deals with these causes and with the functions of the parts. Leaving out of consideration the question of the position of Book i. of the *Parts of Animals*, it may be concluded that Books ii.–iv. of the *Parts of Animals* should come later than the *History of Animals*, and that the *Generation of Animals* should come later that the *Parts of Animals*.

It is by no means easy to arrive at a conclusion about the supposed missing Introduction to the *History of Animals* and the position of Book i. of the *Parts of Animals*. The reason given for supposing that the *History of Animals* once had an Introduction, which has been lost or transposed, has never seemed to me to be satisfactory. The character of that work is very different from that of most of Aristotle's works. From beginning to end he seems to be trying to state simple facts. An Introduction would be less needed in a work of this kind. He himself tells us that the special function of a preface or introduction is to explain the object of a speech, and that an introduction is not needed when the nature of the subject-matter is clear.‡

Again, if it is urged that there should be an Introduction to the *History of Animals*, there is no need to look beyond the first few chapters of that work. After giving a very general account of the parts, habits, dispositions, modes of reproduction, and a few other features of animals, Aristotle says: "So far, I have considered these things in outline, to

* *H. A.* i. c. 6, s. 4; *P. A.* i. cc. 1 and 5. † *P. A.* ii. c. i. 646*a*.
‡ *Rhetoric*, iii c. 14, s. 6.

serve as a foretaste of what is to follow." * This general account is an introduction, and was so regarded by J. Barthélemy Saint-Hilaire. Considering the nature of the subject-matter of the *History of Animals*, such introduction seems to be sufficient.

The last sentence of Book i. of the *Parts of Animals* reads: "Let us try to explain the causes, both general and particular, commencing in the first place from first principles, as we have determined." Now, the first part of Book ii. of the *Parts of Animals* commences from first principles by describing the formation of the so-called elements, then the formation of Aristotle's so-called homœomeria from these elements, and next the formation of anhomœomeria, or complex parts. Therefore, the sentence in question, if correctly placed, indicates that Book i. should immediately precede Book ii.

There is, however, another aspect of the question which should be considered. Book i. of the *Parts of Animals* is of an essentially introductory character, and appears to have been intended to form an Introduction to the zoological works in general. It sets forth the following order of dealing with animals and vital phenomena:—(1) Animals as they appear to us, their natures and parts, should be described; (2) well-defined groups of animals should be described together, and animals which have not been put into well-defined groups should be described separately; and (3) parts of animals and actions and processes, such as progressive motion, sleep, growth, and generation, common to groups of animals, should be described. Now these subjects are described in the *History of Animals*, some much more fully than others, and the method of treatment seems to be based upon that laid down in Book i. of the *Parts of Animals*. Again, some works, such as those on *Progressive Motion of Animals*, *Respiration*, *Sleep*, &c., *Memory and Reminiscence*, and *Generation of Animals*, deal fully with many subjects described only in outline in the *History of Animals*. The method laid down in Book i. of the *Parts of Animals* seems, therefore, to be followed, except as regards the "causes," in the *History of Animals*, together with the works referred to, and Book i. of the *Parts of Animals* seems to be introductory to Aristotle's zoological works generally, as well as to the *Parts of Animals* in particular.

* *H. A.* i. c. 6, s. 4.

On subjects so difficult as those of the order of Aristotle's zoological and related works, and the supposed missing Introduction to his *History of Animals*, dogmatic opinions are out of place, and the following statements are made with some diffidence. The *History of Animals* has an Introduction ending at i. c. 6, s. 4. Book i. of the *Parts of Animals* was written as an introduction to the zoological and related works generally, the first to be commenced having been the *History of Animals.* During the production of this work, it was found to be expedient to treat more fully some of the subjects, such as progressive motion, respiration, sleep, memory, and generation, in separate works, and thus Aristotle had several of his zoological and related works on hand at one and the same time. In connection with these views, the fact already referred to, *viz.*, the absence of a reference to the *History of Animals* as a work in contemplation, is of some importance. Another important fact is that Book vii. of that work, dealing with the development and growth of man, is manifestly incomplete. This indicates that the *History of Animals* occupied Aristotle's attention up to the close of his life.

CHAPTER II.

ARISTOTLE'S METHOD OF INVESTIGATING THE NATURAL SCIENCES.

The basis of Aristotle's method, as set out in his writings, was the ascertainment of facts by actual observation of natural phenomena. He preferred to rely on the evidences of the senses rather than attempt to obtain a knowledge of phenomena by a process of abstract reasoning. He knew that the senses of sight and hearing, in particular, were less keen or reliable in some persons than in others,* that sometimes the senses of touch and smell and, more rarely, those of sight, hearing, and taste, are not trustworthy,† and he believed that Man was surpassed by many animals in the keenness of his senses, excepting those of touch and taste.‡ Without the aid of the senses, however, he did not think that anything could be learned or understood,§ and he held that errors were due to incorrect interpretations of the evidences of the senses which, as far as they were giving indications of their own proper objects of sensation, were reliable, *e.g.*, the tongue would be reliable if used only as an organ of taste, and not as an organ of touch.‖

His method, therefore, was very different from that of Plato, who denied that true knowledge could be based on observations by the senses. Not only did Plato deny that the evidences of the senses could be relied upon, but he also considered the intellectual faculties to be enthralled and their efficiency impaired by association with them. The well-known story of the prisoners in the cave, who could see only the back wall of the cave and the shadows projected thereon by the Sun, towards which their backs were turned,¶

* *H. A.* i. cc. 8 and 9.

† *P. A.* ii. c. 2, 648*a* and *b*; *De Anima*, iii. c. 3, 428*b*, ii. c. 6, 418*a*, ii. c. 9, 421*a*.

‡ *H. A.* i. c. 12, s. 4; *P. A.* ii. c. 16, 660*a*; *De Anima*, ii. c. 9, 421*a*.

§ *De Anima*, iii. c. 8, 432*a*; *De Sensu, &c.*, vi. 445*b*.

‖ *De Anima*, ii. c. 6, 418*a*, iii. c. 3, 427*b*.

¶ *Republic*, vii.

exemplifies Plato's ideas about those who would make observation by the senses a groundwork of true knowledge.

The facts, of which many parts of Aristotle's writings on the Natural Sciences are so full, were collected by him to serve an important purpose in connection with his method of investigation. He says that the characters of animals should first be ascertained before any attempt is made to explain the causes,* and similarly in connection with other subjects he relies on a preliminary ascertainment of facts to serve as the groundwork for processes of inductive reasoning. The importance of this he seems to have been the first to appreciate fully. It has even been said that the inductive method was due to him, but this must be accepted with some qualification. Many thousands before his time employed that method, at least unconsciously. Aristotle was the first, however, to lay down rules according to which inductive reasoning should proceed, and, still more important, he pointed out the value of the inductive method. To this extent, at least, the method is Aristotle's.

Many passages might be cited to show that he was aware of the need for obtaining data by observation before coming to a conclusion, but a few will be sufficient. He begins his description of the reproduction of bees, in *G. A.* iii. c. 10, by pointing out how difficult the subject is, and, after discussing it at great length with the aid of observations on the habits of bees, says that the phenomena were not sufficiently understood, but that, if ever they were to be, the evidences of the senses should be relied on rather than abstract reasoning, but that this should be trusted, provided its conclusions agree with the phenomena.† Again, speaking of possible hermaphroditism in fishes, he says that no males had been seen among the *Erythrinoi*, yet the females were full of products of sexual generation, but adds that he had not so far been able to obtain any result worthy of credit on this subject.‡

Again, when dealing with animals generally, he often recommends his readers to examine the facts for themselves by dissecting the animals, and in *P. A.* iv. c. 5, 680*a*, when describing some of the internal parts of his *Ostrakoderma*, he says that, while some of the parts can be clearly described in words, there are others which should be understood from an actual inspection of them. The thoroughness with which he proposed to investigate living beings is set out in *P. A.*

* *P. A.* i. c. 5, 645*b*. † *G. A.* iii. c. 10, 760*b*. ‡ *G. A.* ii. c. 5, 741*a*.

i. c. 5, 645*a*. In that chapter he says that these ought to be carefully studied, not omitting even the lowest forms of life, which, even if not attractive in themselves, show Nature's handiwork, and afford pleasure to those who inquire into the causes of phenomena and are interested in philosophy. We ought not, he says, to turn away from an investigation of the lower animals, for every part of Nature reveals something to admire, and, just as Heraclitus, warming himself by his kitchen fire, was reported to have told the strangers who called to see him not to be afraid to enter, for gods were present even in his humble dwelling, so Aristotle invites us to study every kind of animal, without being ashamed, for all of them show something natural and beautiful.

Then, with respect to the manner of reasoning on the facts obtained, Aristotle seems to proceed on principles equally sound. He asserts that we commonly conduct an inquiry, not with reference to the question discussed, but with reference to the opponent who argues the question with us, and that, if there is no opponent, we conduct the inquiry until we can satisfy our own objections. Therefore, he proceeds to say, he who intends to investigate completely any subject must take care to satisfy himself on all difficulties arising out of the subject, and this can be done only after he has examined all differences of opinion on the subject of inquiry.*

The above is a brief account of Aristotle's method, as it is set forth in his writings. It might be expected that, after laying down such excellent rules, the results obtained by him would have been uniformly trustworthy, but this was not so. His own practical application of the method was defective. He recognized the importance of a preliminary ascertainment of facts, but he did not appreciate that there were many natural phenomena about which very numerous observations must be made before any generalized statement of them, or any theory explaining them, could be formulated. It must have been necessary for him, just as it has been for investigators since his time, to decide how many observations ought to be made before the generalizing or theorizing process could be safely carried out. There are many indications in his writings on the Natural Sciences that he erred in being satisfied with an insufficient number of observations. Further, he was unaware how necessary it was to make

* *De Cœlo*, ii. c. 13, 294*b*.

many additional observations in order to test the results at which he arrived. This want of appreciation of the value of constant verification of results is evident in many parts of his works. A simple experiment, such as Galileo afterwards made, on the motion of falling bodies, would have caused him to reconsider his opinion that the velocity of a falling body is proportional to its weight. His belief that falling stars, comets, the Milky Way, winds, earthquakes, and some other phenomena were dependent in some way on the existence of a peculiar dry vapour given off by the Earth,* had little else to support it besides abstract reasoning. An examination of the skeleton of a snake would have prevented him from asserting that it had thirty ribs,† and, if he had taken a freshwater eel, a conger, and a bass, skate, or other large fish, and had laid these open to expose the anterior part of the alimentary canal, he would not have stated that a few fishes, like the conger and the freshwater eel, have an œsophagus, but that it is small even in these,‡ or that the œsophagus is entirely wanting in some fishes, and is but short in others.§ He had probably noticed that, in some fishes, the œsophagus was short, and that it was often difficult to determine where it ended and the stomach began, but he did not carry his observations far enough.

The mistakes made by Aristotle have been made by many since his time. There were some cases, however, in which it would be unreasonable to expect Aristotle to succeed in arriving at the truth, even though he had made numerous observations and otherwise carefully followed the rules of his method. His want of success would follow naturally from the want of proper instruments of observation, and an inevitable inability to appreciate the very complicated nature of the phenomena themselves. Consider, for instance, his description, chiefly in *H. A.* vi. c. 3, of the phenomena of incubation of a bird's egg. He evidently believed that the heart was the first part to be developed. His researches on the incubation of a bird's egg, however, were original, and constitute one of the best proofs that he was a careful observer. Another statement, probably the result of many observations, may also be considered. He says that all fishes which have scales are oviparous.‖ Comparatively recent observations have shown that there are many exceptions to this, yet Aristotle can scarcely be adversely criticized

* *Meteorol.* i. and ii. † *H. A.* ii. c. 12, s. 12. ‡ *H. A.* ii. c. 12, s. 3.
§ *P. A.* iii. c. 14, 675*a*. ‖ *H. A.* ii. c. 9, s. 6.

for making the statement. The exception most likely to come under his notice was the Viviparous Blenny (*Zoarces viviparus*), which has very small, delicate scales embedded in its skin. Other viviparous fishes with conspicuous scales, such as *Sebastes norvegicus*, found chiefly in Norwegian waters, and the Surf-fishes (*Embiotocidæ*), found off the Californian and Japanese coasts, were not likely to come under his observation.

As already stated, Aristotle should not be adversely criticized for making such statements, but there are many others which were due to errors of observation. The conger has four double gills on each side, and the parrot-wrasse has three double gills and one single gill on each side, but Aristotle says that each of these fishes has one double gill and one single gill on each side.* Again, the swallow has a very compact gizzard in the form of a thick, nearly circular disc with well-rounded edges, and the gizzard of the sparrow is also very compact, while its œsophagus is comparatively large, for it is usually a quarter of an inch in diameter when gently inflated, with a well-defined part about three-fifths of an inch in diameter, serving as a crop. Aristotle says that some birds, such as, for instance, the swallow and the sparrow, have neither an œsophagus nor a crop of large diameter, but they have a long (*μακράν*) gizzard.† The above statements have been selected because they refer to fishes and birds easily procurable, and to parts of these which Aristotle could have easily examined. One other example, of a different kind, will be given. Like nearly all mammals, the lion and the wolf have seven cervical vertebræ, but Aristotle says that each of these animals has but one bone in its neck, there being no separate vertebræ.‡ It is very likely that, in a case such as this, he accepted what had been told him by others.

The defects thus illustrated, *viz.*, insufficiency of observations and want of a process of verification, explain to some extent why Aristotle sometimes failed, but other causes may be suggested. He attempted to do too much. In consequence of the wide range of his researches, not only in the domain of Natural Science, but also in other branches of knowledge, his work of observing, dissecting, and, to a small extent, of experimenting, must have been carried out only by very strenuous efforts. He allowed himself no time, although he might have had the wish, to make sure of all

* *H. A.* ii. c. 9, s. 4. † *H. A.* ii. c. 12, s. 16.
‡ *P. A.* iv. c. 10, 686*a*; *H. A.* ii. c. 1, s. 1.

his ground as he proceeded. He was like an explorer of a new region, who recognizes its mountain ranges, its chief plains, its great rivers, and, here and there, some minor features which arrest his attention, but who must press forward, with no opportunity for tracing a river to its source or ascertaining the relative positions and heights of the various peaks. While admitting the importance of obtaining a knowledge of the phenomena by observation, he seems to have been determined to formulate as many generalized statements as possible. He appears to admit this when he says that we must try to state what appears to us (τὸ φαινόμενον), nor should this be considered to be of the nature of presumption, but should deserve respect, when anyone, having to deal with matters of very great difficulty and urged by a desire for investigating philosophy, contents himself with slight data.*

A further cause of failure, closely connected with Aristotle's apparent willingness to content himself with slight data and mere approximations to the truth, deserves special mention. It is clear that any defect arising from insufficient data would have to be remedied in some way, and Aristotle, like many other ancient Greek philosophers, sometimes tried to do this by relying on certain ideas which were treated by him as if they were more authoritative than the data themselves. These ideas were brought forward, often without any apparent consideration as to whether or no they were relevant to the question at issue, and used in much the same way as axioms and postulates are used by geometricians. The result was a remarkable mixture of inductive and deductive reasoning.

The arguments which led Aristotle to conclude that there could not be a separate void,† and that the blood of the right chamber of the heart and of the right side of the body is hotter than that of the left,‡ furnish examples of the defects of method caused by the use of ideas of the kind referred to above.

Aristotle's arguments against the existence of a separate void are too long to be given in full, but the following is an epitome of what seem to be the chief parts of them. In a void, if this existed, a body could not be in motion, for a void, being a mere privation of matter, could not present differences of position and direction, such as above and below,

* *De Cœlo*, ii. c. 12, 291*b*. † *Physics*, iv. c. 8.
‡ *P. A.* ii. c. 2, 648*a*, iii. c. 4, 667*a*.

upwards and downwards, and so the upward and downward motions natural to bodies could not take place.* Again, if bodies of similar shapes pass through a medium, such as air or water, then those which have a greater driving-force (ῥοπή)—due to their heaviness, in the case of bodies to which a downward motion is natural, or to their lightness, in the case of bodies to which an upward motion is natural—will move more quickly through the same distance. This ought to happen also when the bodies pass through a void, but this is impossible, for what reason is there for the swifter motion? In water or other medium this happens, of course, since the heavier bodies, *e.g.*, divide the medium more quickly by reason of their greater heaviness. A body in motion divides the medium by reason of its shape or its driving force (ῥοπή), and, when there is no medium, all bodies ought to move with equal velocities, but this is impossible.† Having thus argued, he says that it is clear therefore that there cannot be a separate void (κεχωρισμένον κενόν).‡ Without attempting to analyse the above arguments any further, it will be evident that the introduction of ideas, such as, for instance, that it is necessary to distinguish upward and downward directions before it can be said that motion is possible, that bodies have certain motions natural to them, and that the velocity of a body depends on its shape and on its heaviness or lightness, qualities considered to be inherent in the body, make it impossible to come to any correct conclusions.

Finally, Aristotle's conclusion that the blood of the right chamber of the heart and of the right side of the body is hotter than that of the left chamber or side may have been based, in part, on observations, for he was aware of differences of consistency, turbidity, and temperature in the blood from different parts of the same animal. Observations were not relied on, however, to any important extent in this instance. His arguments in *P. A.* ii. c. 2, 648*a* show clearly that his conclusion that the blood of the right chamber of the heart and of the right side of the body is hotter than that of the left chamber or side followed from his idea that the right is nobler or more honourable than the left. This idea, it will be noticed, has no necessary connection with the question of differences of temperature of the blood in different parts of the body.

* *Physics*, iv. c. 8, ss. 3 and 4. † *Physics*, iv. c. 8, ss. 11 and 12.
‡ *Physics*, iv. c. 8, s. 16.

CHAPTER III.

CELESTIAL, ATMOSPHERIC, AND TERRESTRIAL PHENOMENA.

Aristotle's descriptions and explanations of these three classes of phenomena are such that it is proposed to treat of them in one and the same chapter. .To treat of them separately would erroneously suggest a division such as he never effected. At the present time, the subject-matter dealt with in this chapter would be properly assigned to the sciences of astronomy, meteorology, physical geography, and geology. Aristotle's *Meteorology* and his work on the *Heavens* contain, in fact, much information about the heavenly bodies, rainbows, winds, earthquakes, the sea, periodical changes of land and sea, and other phenomena, but the causes assigned for some of these, and the manner in which they are described, show that he did not appreciate their true nature. Such want of appreciation may be seen from the facts that he considered the Milky Way to be due to causes much the same as those by which he believed comets to be produced, that both depended on the ascent of certain vapours from the Earth, and that earthquakes, lightning, and thunder were due to the same general cause as winds. His descriptions and explanations, often accompanied by the views of other philosophers, are of historic value, and he records some events, such as, for example, some appearances of comets, changes in the distribution of land and sea, and volcanic eruptions and earthquakes, which are very interesting in themselves.

Inaccurate though his explanations of phenomena often are, yet he shows a desire to reason out rather than to guess at the causes of such phenomena, and, compared with those of his predecessors, his views are generally founded on much more carefully considered arguments.

The fundamental principles on which his arguments were based, *viz.*, the formation of terrestrial matter from four elements, the natural motions of which were upwards

from the centre, in the cases of fire and air, and downwards towards the centre, in the cases of earth and water, and the existence of a fifth element, æther, having a circular motion and existing at a great distance from us, vitiated many of his results, and sometimes caused him much trouble when attempting to show that his results were in accord with the phenomena. Examples of this will be seen in his explanations of falling stars and thunderbolts.

Many of the problems which Aristotle sought to solve would require the use of instruments which he did not possess, and, without the aid of these, he could scarcely do otherwise than fail. His explanations of celestial, atmospheric, and terrestrial phenomena are often of a fanciful nature and constitute some of his least valuable work. Some of the phenomena he records are very interesting, as already stated, and, in the following description, his records of this kind will be discussed after his opinions on the causes to which the phenomena were due have been considered. As far as possible, the celestial phenomena will be discussed first, then the atmospheric, and, finally, the terrestrial.

According to Aristotle, there is but one Kosmos or Universe; it is spherical in form and finite in magnitude; it includes all matter, and outside it there is neither place nor time; it was not generated, neither can it be destroyed; it rotates to the right, and its rotation is uniform. This is an epitomized statement of Aristotle's views on the Kosmos, as set out at great length in his *De Cœlo*, i. cc. 5–12, ii. cc. 1, 4, 5, and 6. Being in the form of a sphere, the Kosmos was capable of rotating so as to occupy the same position and space at all times. This form was assigned to it because the Kosmos is necessarily perfect, and the only perfect geometrical figure is the sphere, which Aristotle considered to be representative of perfection, uniformity, and eternity. He decided that the Kosmos was finite for several reasons, one being that there could not be an infinite square, sphere, or other geometrical figure,* and he defined the infinite to be that of which, taking any part whatever for consideration, there is always something beyond, for it is not that beyond which nothing exists.† He says that the infinite exists in δύναμις, *i.e.*, potentially, but this must not be understood to mean that the infinite will exist, in the same way as it may be said that if a material is capable of existing in the form

* *De Cœlo*, i. c. 5, 272*b*. † *Physics*, iii. c. 6, ss. 7 and 8.

of a statue then it will exist in that form.* The infinite can exist only as an object of contemplation, but the capability of division without end gives to the potential infinite some kind of actual existence.† The upper parts of the Kosmos are full of æther, which is of such a nature that it is always moving in a circular path, and, being of this nature, it cannot have either heaviness or lightness; further, it was not generated and could not be destroyed, being incapable of change, quantitative or qualitative.‡ It was of this element that Aristotle believed the heavenly bodies to consist.§ He says that some believed that the stars were of fire, but it should be understood that they were not, nor were they carried round in a medium of fire.‖ In his *De Cœlo*, ii. cc. 7 and 8, he speaks of the Sun and Stars being fastened (ἐνδεδεμένος) in the Heavens. This seems at first sight difficult to understand, suggesting as it does the necessity of supporting almost incalculable masses, but Aristotle's assumption, previously referred to, that the heavenly bodies are of æther, which has neither heaviness nor lightness, would remove any difficulty of this kind. His ideas about the fixing of the heavenly bodies in the Heavens were borrowed, in part at least, from earlier philosophers, especially Pythagoras and Parmenides.

Beneath the higher parts of the Kosmos, filled with æther, was the zone, if it may be so called, of fire, which Aristotle supposed to be between the æther and the air, beneath which were water and earth.¶ In the zone of fire, however, he contemplated the presence of a dry, earthy exhalation, to be referred to later, and of air, probably in the same way that he recognized the presence of watery vapour in the air.

Having set out, so far, his views on the stars and other heavenly bodies, Aristotle's explanations of the way in which the heat and light of these bodies is caused will be considered. Many difficulties arise in the mind of anyone reading through his statements on this subject, chiefly in his *De Cœlo*, ii. c. 7, but his explanation may be expressed as follows:—Observations on the motion of missiles show that they become highly heated or are even ignited, and, he adds, the air is similarly affected. Since, then, heat is produced by the

* *Physics*, iii. c. 6. s. 2.
† *De Gener. et Corr.* i. c. 3, 318*a*; *Metaphys.* viii. c. 6, 1048*b*.
‡ *De Cœlo*, i. c. 2, 269*b*, i. c. 3, 269*b* and 270*a*; *Meteorol.* i. c. 3, s. 4.
§ *Meteorol.* i. c. 2, s. 1; *De Cœlo*, ii. c. 7, 289*a*; *De Mundo*, c. 2, 392.
‖ *De Cœlo*, ii. c. 7. ¶ *Meteorol.* i. c. 3, s. 14; *De Cœlo*, ii. c. 4, 287*a*.

friction of bodies in motion, the heavenly bodies moving in their respective courses still more readily cause the ignition of the *air* beneath them, this being more of the nature of fire than is any solid missile. The heavenly bodies themselves are not heated. Where the Sun happens to be fixed the heating effects are intense, but, in *Meteorol.* i. c. 3, s. 21, he says that the Sun, which in an especial degree seems to be hot, appears to be white and not fiery. It has been stated already that he did not believe that the stars were of fire, nor that they were carried round in a medium of fire. He seems to have believed that they moved in contact with the medium of *fire* or *air* within their spheres of motion.*

Such were Aristotle's views. They are difficult to understand, not only because they are not explained sufficiently fully, but also because they are based, in part at least, on fanciful assumptions. It is not clear what was the nature of the substance the ignition of which was caused by the motion of the heavenly bodies, except that it was intermediate between fire or flame and air, like one of the substances which Alexander, Simplicius, Philoponus, and some other ancient writers identified with Anaximander's infinite or primitive matter. His assertion that the Sun appears to be white and not fiery is strange, and suggests that he had not seen a white-hot fire. It will be seen, in the discussion on his views on heat phenomena, that he greatly underestimated the intensity of heat of an ordinary red-hot fire. Again, Aristotle does not satisfactorily explain why the heating effect is so intense where the Sun happens to be secured. In an attempt to explain this, in *Meteorol.* i. c. 3, s. 20, he says that the motion of the Sun is sufficiently rapid and the Sun is near enough to us, for the moving body should not be too far away and its motion should be rapid, for the heat to be effective. The stars, he says, certainly move rapidly, but are too far away, while the Moon is nearer, but her motion is slow. The statement that the heavenly bodies are not heated would be difficult to understand were it not for Aristotle's assumption, already referred to, that the heavenly bodies are of æther, which is incapable of change.

According to Aristotle the stars are spherical, but they neither rotate nor revolve of themselves, being secured in the circles of the Heavens, which are rotating.† His opinion that the stars are spherical was also held, he says, by others.‡

* *De Cœlo*, ii. c. 4, 287*a*, ii. c. 7. 289*a*.

† *De Cœlo*, ii. c. 8, 289*b*, and 290*a*.

‡ *De Cœlo*, ii. c. 8, 290*a*.

That the Moon is spherical is shown, he says, by her phases and by solar eclipses.* He says also that the Earth is spherical, this being shown by eclipses of the Moon, and that geometers had calculated the circumference of the Earth to be about forty-six thousand miles.† Other philosophers, before Aristotle's time, believed that the Earth was spherical, *e.g.*, the Pythagoreans, according to Zeller.‡ In opposition to the Pythagoreans and others, he held that the Earth was the centre of the Kosmos, and this conclusion was based on his assumptions about the nature of the elements and their proper motions, for, according to these assumptions, motion about a centre, whether a motion of rotation or revolution, would not be natural to the Earth or any part of it. He decided that the Earth was at rest at the centre of the Kosmos, and must necessarily tend to that position for several reasons, one being that heavy bodies thrown upwards, even to a great height, fall directly downwards to the places whence they are thrown,§ for he considered that the Earth would act like any of its parts. Aristotle's belief, previously referred to, that, passing outwards from the centre, earth, water, air, and fire are arranged above one another in the order named, seems to be a development of Anaximander's belief that the earth, the air, and an envelope of fire, enclosing the whole, were produced by successive processes of separation from his fluid primitive matter.

Before proceeding further with Aristotle's views on the Earth and terrestrial phenomena, some of his statements about certain celestial and atmospheric phenomena, such as falling stars, the Milky Way, and rainbows, will be considered.

These phenomena, according to Aristotle, have a less orderly arrangement than the stars and planets.‖ The explanations he gives to account for the formation of falling stars, comets, the Milky Way, and various other kinds of luminous and moving appearances in the sky are somewhat alike. He bases most of his explanations on an assumed ascent of exhalations from the Earth, parts of such exhalations being afterwards ignited in consequence of the motions of the upper regions of the Kosmos. The exhalations were supposed to be of two kinds: (1) an essentially watery vapour,

* *De Cœlo*, ii. c. 11. † *De Cœlo*, ii. c. 14, 297*b* and 298*a*.
‡ *History of Greek Philosophy*, translated by S. F. Alleyne, 1881, vol. i. p. 454. § *De Cœlo*, ii. c. 14, 296*b*. ‖ *Meteorol.* i. c. 1, s. 2.

and (2) an essentially dry, smoke-like exhalation from dry earth. This ascended higher than the watery vapour, and was the one which Aristotle believed to be ignited. The modes of arrangement and the sizes of the ignited exhalations varied, and various names were given them. Aristotle describes some of them. His descriptions are neither full nor clear, but he refers to falling stars and, apparently, fiery meteors to which he gives the name "aix," *i.e.*, something which rushes impetuously, and to blood-red and other flame-like appearances, which seem to include auroras.*

In another passage Aristotle modifies his views on the mode of production of falling stars. He was met by the difficulty that the downward motions of these bodies were not such as might be expected from an ignited exhalation, for the natural motion of fire is in an upward direction. To overcome this difficulty, he says, in a passage difficult to understand, that hot matter is violently pressed out downwards, in consequence of the air being compressed by the cold, and thus the motion is more like that of a falling body than that of flame.†

After commenting on the views of Anaxagoras, Democritus, and others on the nature of comets, Aristotle says that the dry and hot exhalations, referred to already, beneath the moving parts of the heavens, together with the underlying air, are whirled round the Earth, and that whatever they meet is ignited, provided it is of the proper constitution, a falling star being thereby produced.‡ Under conditions such that the resulting ignited matter becomes compressed and burning proceeds for a long time at a steady rate, and simultaneously an exhalation of suitable constitution rises from below and meets with the burning matter, the falling star becomes a comet.§ When the ignition occurs in a lower region of the Kosmos, a comet appears as a separate phenomenon, but if the ignition occurs beneath some star or planet, then this becomes a comet.‖ The first kind of comet is probably meant to be one with a conspicuous tail, and the second one with a conspicuous nucleus and a tail less distinct.

In order to explain the appearance of the Milky Way, Aristotle again made use of his theory of ignited exhalations. He believed that if ignition of a dry exhalation beneath a

* *Meteorol.* i. c. 4, ss. 5 and 6, and c. 5, s. 1.
† *Ibid.* i. c. 4, ss. 7–10.
‡ *Ibid.* i. c. 7, ss. 1 and 2.
§ *Ibid.* i. c. 7, s. 3.
‖ *Ibid.* i. c. 7, s. 5.

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star could produce a comet, as stated previously, then a similar result would be produced beneath the vast number of stars which are collected together in the Milky Way.* The milky appearance he considered to be due to the tails, apparently coalesced, of the numerous comets or comet-like effects thus produced.†

Amid all these fanciful explanations, it is quite clear that Aristotle fully appreciated one fact, *viz.*, the existence of numerous stars, many of large size, in the Milky Way.

He explains the views of other philosophers, *viz.*, the Pythagoreans, who believed that the Milky Way was the path of the planets, Anaxagoras and Democritus, who held that it was the light of certain stars, which, hidden from the Sun by the Earth, shone with a light of their own so as to produce a milky aspect, and some philosophers who considered the Milky Way to be caused by reflection. This, he says, was nearly all that had been said by others on this subject.‡

Rainbows and what he calls halos, parhelia, and rods or streaks of light are, Aristotle says, all caused by *anaklasis*.§ *Anaklasis* means a bending or breaking aside, and, as used by Aristotle in his statements about light, a reflection.

It is not clear that all Aristotle's statements about halos relate to the phenomena now called by that name, but most of them seem to do so. Halos, white and coloured, have been seen about the Sun, the Moon, and the planet Venus, when these celestial bodies were shining through cirrus or like clouds. These clouds are now believed to contain vast numbers of ice crystals, which act like prisms. Those crystals which send the maximum amount of light to the eye of the observer form a circular ring, and the effect of refraction by these is to produce, in the case of a coloured halo, a circular spectrum-band with the red on the inner side and not on the outer, as in a primary rainbow.

Aristotle's explanation of the way in which a halo is produced has a superficial resemblance to the above, but he considers that it is formed when the light of the Sun, the Moon, or a bright star or planet, shines through a uniformly moist cloud and is reflected by a circular ring of watery particles which form part of the cloud, and act like so many small mirrors.‖ He says that the rainbow and the halo

* *Meteorol.* i. c. 8, ss. 11 to 13.
† *Ibid.* i. c. 8, s. 20.
‡ *Ibid.* i. c. 8, ss. 4 and 10.
§ *Ibid.* iii. c. 2, s. 7.
‖ *Ibid.* iii. c. 2, s. 2, c. 3, ss. 2, and 7 to 9.

differ in the design (ποικιλία) of their colours,* but he does not explain in what way they differ, so that it cannot be said that he was aware of the difference between the arrangements of the colours, previously referred to, of a primary rainbow and a coloured halo. In *Meteorol.* iii. c. 3, ss. 10 and 11, when dealing with the colours of solar halos, he says that the mirrors, although severally invisible on account of their smallness, are contiguous and form one ring in which the Sun is reflected so that a whiteness of the halo is evident. He states correctly that halos are less frequently seen about the Sun than about the Moon.†

Aristotle refers, in several passages, to parhelia or mock suns, but some of his statements about them are incorrect. Like halos, in association with which they are sometimes seen, parhelia are caused by refraction of sunlight shining through a cirrus or like cloud containing minute ice crystals. The parhelia usually occur to the right and left of the Sun, at a distance of about 22° therefrom. Aristotle says that parhelia are due to reflection of the visual rays from something to the Sun,‡ and, it seems, from *Meteorol.* iii. c. 6, s. 5, that this something is a dense mist or cloud, the watery vapour of which is in the act of condensing into raindrops and so uniformly constituted as to form, in effect, an even mirror reflecting an image of and of the same colour as the Sun, the reflection being compared with that which takes place at the surface of polished bronze.

He was aware that the appearance of a parhelion was an indication of unsettled weather.§ Parhelia are produced, according to Aristotle, to the right and left of the Sun, and neither above it nor below it, and he adds correctly that they are not formed very close to the Sun nor very far away.‖

The appearance and mode of formation of certain streaks of coloured light, which Aristotle calls "rods" (ῥάβδοι), are described by him, but his descriptions are difficult to understand. The streaks of light are probably those which are seen among clouds at sunrise and sunset, producing the magnificent colour effects, which are so well known.

Aristotle says that the "rods" usually appear about sunrise and sunset, and always to the right or left of the

* *Meteorol.* iii. c. 4, s. 9.
† *Ibid.* iii. c. 3, s. 12.
‡ *Ibid.* iii. c. 6, s. 1.
§ *Ibid.* iii. c. 6, s. 6.
‖ *Ibid.* iii. c. 2, s. 6, iii. c. 6, s. 7.

Sun.* It is scarcely necessary to say that the streaks of light producing colour effects at sunset and sunrise are often seen above and below the Sun, as well as to the right and left. He seems to have believed that, unlike parhelia, the "rods" were caused by reflection of a cloud, probably a white one, in certain very watery clouds near the Sun. In order to explain his meaning, he refers to the appearance of a cloud when seen directly and when seen by reflection in water. In the former case, he says, the cloud is quite colourless, but, when seen in water, it seems to be full of "rods."† Again, in an earlier passage, he says that the reflection of the cloud in water is some colour of the rainbow, for the visual rays being weakened in consequence of the reflection, the white is changed to some colour between white and black.‡

To give a correct explanation of passages such as these does not seem to be possible. The splendid colour effects of the Grecian seas may well have excited the imagination and given rise to popular beliefs, with which Aristotle would be acquainted, but the above passages seem to be the results of abstract reasoning. He knew nothing, of course, about the composite nature of white light, and was obliged to make use of some ingenious assumptions to account for colour phenomena. He assumed that minute drops of water, acting as mirrors, may be so small as not to reflect the form of an object, but colour only, such colour depending, in part at least, on the size of the drops. He believed that the "rods" appeared when the very watery clouds, referred to above, varied in density and content of watery vapour, so that the mirrors formed by the minute water drops varied in size. Under these conditions, he considered that, in accordance with the assumptions set out above, coloured streaks of light, *e.g.*, red or yellow, would be produced, for he says:—"The 'rods' are due to the irregularity of the mirror, not as regards form but colour."§

Aristotle's explanations of rainbows, primary and secondary, and their colours are given at great length, chiefly in *Meteorol.* iii. cc. 4 and 5. Compared with most of his explanations of other natural phenomena, those of rainbows are particularly full, ingenious, and interesting. Read in connection, however, with the more important facts about

* *Meteorol.* iii. c. 2, s. 6, iii. c. 6, s. 7.
† *Ibid.* iii. c. 6, ss. 1 and 2.
‡ *Ibid.* iii. c. 4, s. 28.
§ *Ibid.* iii. c. 6, ss. 3 and 4.

rainbows discovered long after his time by Theodorich and De Dominis on the refractions by the raindrops and reflections at their surfaces, by Descartes on the concentration of the rays of light in particular directions, and by Newton on the differences of refrangibility of different coloured rays, Aristotle's explanations are cumbersome and often fanciful. It is not easy to understand his meaning, and there are indications in his description that he found the explanations very difficult. He makes several assumptions, most of them faulty, and it is not always clear on which of these assumptions he relies when attempting to explain certain details of the phenomena. The following is an epitome of Aristotle's views, from which the peculiarities of his explanations, referred to above, will be evident. It will also be noticed that he speaks of the rays of light being reflected towards the object seen. Visual rays, he says, are reflected from all smooth surfaces, such as those of water and air, and such reflection takes place from compressed air and also from air which is not compressed, if the visual rays are weak, just as happened in the case of one man whose sight was weak, for he always saw an image of himself in front of him, as he walked.* The reflection is stronger from water and especially from vapour which is just being condensed into water, for then each of its parts acts like a mirror.† On account of the extreme smallness of such mirrors, however, colour only and not form will be seen, but the succession of mirrors similarly situated will give a continuous band of similar colour. The same reasoning applies to all the mirrors, and so a rainbow is formed.‡

Again, a rainbow is caused by the reflection of visual rays by a cloud to the Sun, the cloud being dark and the visual rays having to extend through a long distance. A bright object, however, shining through anything dark or in anything dark—for, he adds, it makes no difference which it is—is red. In order to exemplify this, he remarks that the Sun appears to be red when seen through mist or smoke, and that the flame of a fire of green wood appears to be of a red colour, by reason of its being seen mingled with a large amount of smoke.§ He says that this explains why one of the colours of the rainbow is red.‖ Continuing his

* *Meteorol.* iii. c. 4, ss. 2 and 3.
† *Ibid.* iii. c. 4, s. 5.
‡ *Ibid.* iii. c. 4, ss. 6 and 7.
§ *Ibid.* iii. c. 4, ss. 9–11.
‖ *Ibid.* iii. c. 4, s. 12.

explanations, he introduces another idea into his train of reasoning, saying that distant objects seem to be darker because the visual rays fail to reach them, or only partially do so, or because the rays are weakened by reflection. From one or both of these causes, therefore, a bright or white object may appear to be of some colour between white and black, *e.g.*, light red, greenish yellow, or dark blue, which successively approach black. If the visual rays are strong, white would be changed to light red; if less strong, white would be changed to greenish yellow; and if weak, it would be changed to dark blue. Now the greater the periphery from which the visual rays extend to the Sun, the stronger and more concentrated the rays, but the outer periphery of the primary rainbow is the greatest, and therefore its colour is light red, which is nearest to white. Reasoning in the same way, it follows that the inner part of the primary rainbow is dark blue, and the middle part greenish yellow.*

Aristotle proceeds to deal with the secondary rainbow and says that this also has three colours, formed by reflection, the inner part of the secondary rainbow being light red, the outer part dark blue, and the intermediate part greenish yellow. His explanation of this phenomenon is meagre and presents many difficulties, but the following seems to represent his views. The secondary rainbow has its colours duller than those of the primary and also in inverse order, compared with those of the primary, for the same reason, for the visual rays are weaker because the reflections causing the secondary rainbow take place at a greater distance than those causing the primary rainbow, thus causing the colours to be dull. Again, more rays extend to the Sun from the inner part of the secondary, which inner part is nearest the observer, like the outer part of the primary rainbow. The visual rays, therefore, being more numerous and stronger at the inner periphery, its colour will be light red, for reasons similar to those given when explaining the order of the colours of the primary rainbow, and the other colours proceeding radially outwards will be greenish yellow and dark blue.†

It will be evident that his explanations depend on some ingenious assumptions, notably that relating to the production of colour-effects by the weakening of the visual

* *Meteorol.* iii. c. 4, ss. 20–25. † *Ibid.* iii. c. 4, ss. 30–32.

rays, but what will, perhaps, cause most surprise is that he made such a persistent attempt to explain so difficult a series of phenomena.

Aristotle also discusses the size of the rainbow, and makes some very interesting statements about the conditions under which it could be seen at Athens. In *Meteorol.* iii. c. 2, s. 3, he says that the arch of the rainbow is never greater than a semicircle, and in *Meteorol.* iii. c. 5, proceeds to give a geometrical proof of this. Aristotle's statement is substantially correct for an observer on the earth's surface, for the effect of refraction in the case of the rainbow is inappreciable. That the arch is sometimes greater than a semicircle is, however, well known, the arch being so when the observer is at some high elevation.

An error, however, occurs in *Meteorol.* iii. c. 2, s. 3, where it is stated that, at sunset and sunrise, the circle of the rainbow is least but the arch is greatest, and that, when the Sun is high, the arch is less but the circle greater. The external radius of the primary rainbow is constant, being about 42°, and that of the secondary rainbow is also constant, being about 54°. Still, it is clear that Aristotle attempted to make observations in a thorough manner, and it should be remembered that it was not possible to explain the constancy of the angular dimensions of the rainbow before Descartes proved that a concentration of the rays occurs in certain directions. Aristotle also says, in a passage which shows that he was a keen observer, that, after the autumnal equinox and during the shorter days, a rainbow is possible at all hours, but, in the summer, it is not possible about midday.* He probably intended this statement to refer to the appearances of rainbows at Athens. He attempts to explain it in *Meteorol.* iii. c. 5, but his explanation is defective, because he was not in possession of correct data.

A straight line from the centre of the Sun to the centre of a rainbow passes through the observer's eye, and, therefore, if the Sun is more than 54° above the horizon, not even the outer part of a secondary rainbow would be visible to an observer at the sea-level at Athens. Referring to Fig. 1, it will be seen that, at midday, June 21st, the altitude of the Sun at Athens $= 90° - (38° - 23° 28') = 75° 28'$, the latitude of Athens being 38° and the inclination of the

* *Meteorol.* iii. c. 2, s. 3.

ecliptic 23° 28′. Clearly, therefore, a secondary rainbow, and still less a primary rainbow, would not be visible about midday. At the autumnal equinox (Sept. 21st) it is evident

FIG. 1.

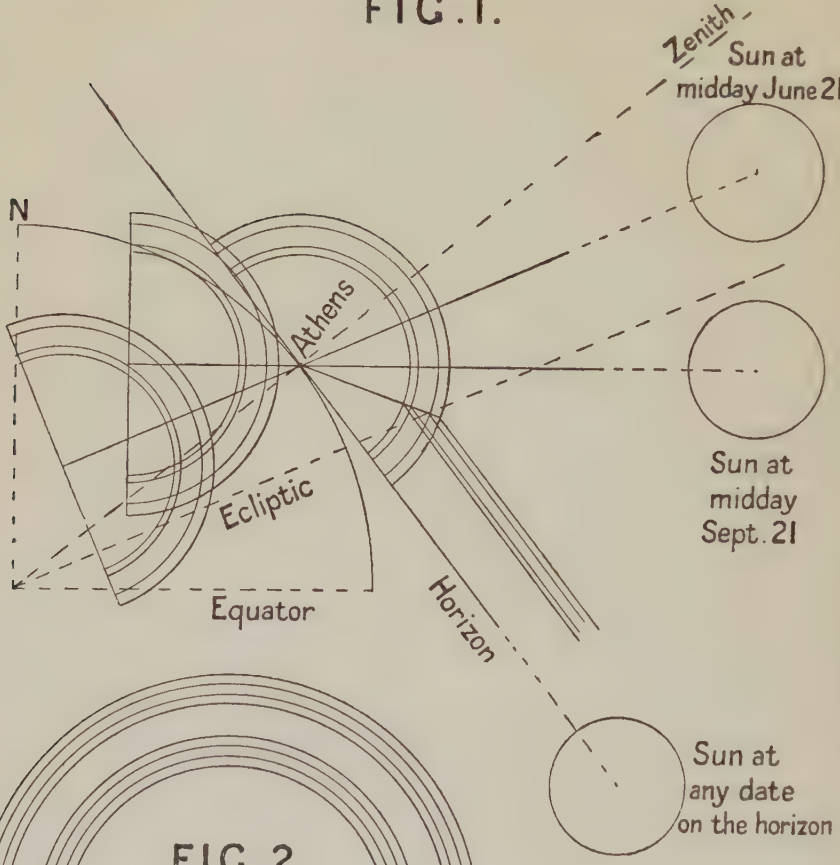


FIG. 2.

that, at midday, the altitude of the Sun at Athens is 52°, and some part of a secondary rainbow might be seen, even at midday, and part also of a primary rainbow could be seen at midday, during the shorter days of the year. It will be

noticed that, in Fig. 1, the rainbows are shown greatly magnified and in positions suitable for showing the lifting up of a rainbow at Athens at midday, as the year advances.

Several other interesting statements about rainbows are made by Aristotle. He says, for instance, that, in consequence of the juxtaposition of the light red and greenish yellow, an orange colour is seen in some cases,* and that the colours of the rainbow, light red, greenish yellow, and dark blue, are almost the only ones which painters cannot produce by mixing other colours.†

It is well known that various colours can be produced by mixing red, yellow, and blue pigments in suitable proportions. Aristotle considered the extreme colours of the rainbow to be some shade of red and of blue respectively, but it is not clear what was the intermediate colour; some passages suggest that it was green, others, like the one cited above from *Meteorol.* iii. c. 2, s. 5, suggest that it was yellow. He calls it πράσινον, which usually meant leek-green, but it is unlikely that he misunderstood what was known by painters about the mixing of colours, and, mainly for this reason, it has been assumed in this chapter that the intermediate colour was some shade of yellow. The colours and their arrangement, according to this view, are shown in Fig. 2. The colour ξανθόν, which Aristotle considered to be due to the juxtaposition of coloured lights. *viz.*, greenish yellow and light red, is assumed to be orange, a colour which ξανθόν sometimes denoted. It will be noticed that Aristotle mentions four colours of the rainbow and yet, in some passages, says that each rainbow has three colours only. The inconsistency is apparent only, for he makes it clear that the three colours are those which he considered to be due to reflection. The number of colours of the rainbow which can be distinguished varies with different observers, being usually five, six, seven, or even more. Aristotle discusses the possibility of the formation of more than two rainbows, but concludes, incorrectly, in *Meteorol.* iii. c. 4, s. 33, that three or more are not produced. With respect to lunar rainbows, he says correctly that these are only rarely seen, and adds that, during a period of more than fifty years, he had known of only two instances.‡ The colours of a lunar rainbow can be seen, but are by no means

* *Meteorol.* iii. c. 4. s. 26. † *Ibid.* iii. c. 2, s. 5.
‡ *Ibid.* iii. c. 2, s. 9.

conspicuous. Aristotle, however, states that a lunar rainbow seems to be quite white.*

He also refers incidentally to the formation of rainbows in spray raised by oars from the sea, or in spray scattered by hand away from the sun, but he states incorrectly that, in these cases, the colours are more like those seen about lamps, there being, apparently, not a light red but a purple colour.†

This represents the main part of Aristotle's descriptions of rainbows. Many of his statements are inaccurate, as has been mentioned already, but yet none of his work on celestial, atmospheric, and terrestrial phenomena shows more clearly the use of a careful method of inquiry. Further, his descriptions of the way in which rainbows and their colours are produced serve to illustrate some of the difficult passages on light and colour which will be considered in Chapter iv.

Unlike some ancient philosophers, Aristotle did not believe that air, when in motion, was wind, while the same air, when condensed, was rain.‡ He believed that rain originates from an exhalation, essentially vaporous, and wind from another exhalation, essentially dry or smoke-like, both being raised by the heat of the Sun and always associated together.§ He was influenced by observations showing that during dry years, when the dry and smoke-like exhalation was most abundant, winds were most frequent, while the vaporous exhalation was most abundant during wet years.‖

Aristotle knew that winds were due to the action of solar heat, but beyond this his views on their production were untrustworthy. The action of solar heat is to rarefy parts of the atmosphere, and the rarefied parts rising upwards are replaced, more or less violently, by colder and heavier air. These processes, so well-known to result in the occurrence of winds, do not seem to have been known to Aristotle. He believed that the dry, smoke-like exhalation was, as he says in various passages, the origin, nature, or substance of winds. Like those of other ancient philosophers, his ideas about the composition of the atmosphere were very crude, and it is difficult to understand what he considered the dry, smoke-like exhalation to be, but it is

* *Meteorol.* iii. c. 4, s. 28.
† *Ibid.* iii. c. 4, ss. 17–19.
‡ *Ibid.* ii. c. 4, s. 7.
§ *Ibid.* ii. c. 4, ss. 2–5.
‖ *Ibid.* ii. c. 4. s. 10.

probable that it was hot air mingled with humic and other effluvia rising from the hot earth. It may be mentioned here that, in the Aristotelian work, *De Mundo*, c. 4, 394, it is stated that wind is nothing else but a large quantity of compressed air in motion. This work was not written by Aristotle.

His views on the wet or vaporous exhalation are much easier to understand, and are set out at great length in *Meteorol.* i. cc. 9–12. He probably did not know that water vapour is diffused throughout the atmosphere, but he gives a substantially correct explanation of the formation of rain and clouds, for he says that the vapour raised by the Sun's heat and by any other celestial source of heat is cooled and condensed and descends to the earth, and that clouds result from a separation of watery vapour from the air.*

Dew and hoar-frost are formed from watery vapour during clear, calm weather.† Hail, he says, is ice, and is produced most in spring and autumn, less frequently in summer, and seldom in winter.‡ It is formed in consequence of a rapid freezing of water separated from the air, the freezing being so rapid that the water is converted into ice before it reaches the ground.§ The freezing is more rapid, he says, if the water is warm before freezing commences.‖ Some examples of this, which Aristotle records, will be considered in Chapter iv. Up till his own time, Aristotle says, three different views about the causes of earthquakes had been put forth.¶ According to him, Anaxagoras believed that they were caused by the æther of the upper regions bursting into the under parts and hollows of the Earth.** Democritus assumed that the Earth, already saturated with water and, in addition, receiving quantities of rain-water, became shaken thereby.†† Anaximenes believed that the Earth was shaken by masses falling in, such masses having been broken away during a process of drying the Earth, which he assumed to be quite moist.‡‡

Setting forth his own views on earthquakes, Aristotle says that the Earth of itself is dry, but, on account of the rains, becomes moist, so that, being subjected to the action of the Sun's heat and its own internal heat, a large quantity

* *Meteorol.* i. c. 9, ss. 2–4.
† *Ibid.* i. c. 10, s. 4.
‡ *Ibid.* i. c. 12, s. 1.
§ *Ibid.* i. c. 12, ss. 13 and 14.
‖ *Ibid.* i. c. 12, s. 17.
¶ *Ibid.* ii. c. 7, s. 1.
** *Ibid.* ii. c. 7, s. 2.
†† *Ibid.* ii. c. 7, s. 5.
‡‡ *Ibid.* ii. c. 7, s. 6.

of a spirituous vapour (πνεῦμα) is generated both without and within it, and this vapour flows sometimes into and sometimes out of the Earth.* To this vapour he attributes certain properties, *viz.*, an excessive degree of mobility, a very rapid inherent velocity, and great tenuity and consequent penetrating power.† Neither water nor earth, he says, is a cause of earthquakes, but spirituous vapour in motion, when that which has been given off outwards happens to flow inwards, and, for this reason, earthquakes are more frequent and violent during calm weather.‡ In a more intelligible passage, he says that earthquakes are due to violent movements of spirituous vapour (πνεῦμα) or wind (ἄνεμος) in the interior of the Earth, such vapour or wind sometimes issuing forth like a hurricane.§

By comparing the dates of recorded earthquakes in Britain, France, Switzerland, and other countries, it has been concluded that earthquakes are more frequent in winter than in summer. According to Aristotle, they were more frequent in spring and autumn, because these seasons favoured the generation of the spirituous vapour; summer and winter, on the other hand, were rather periods of rest, the one because of its heat, and the other because of its frost.‖ He also concluded that earthquakes were usually more frequent and violent by night than by day.¶

The violence of earthquakes, in so far as it is manifested in the destruction due to them, depends in no small degree on the character of the geological formations of the area of disturbance. Aristotle believed that earthquakes were more violent and also more frequent in districts where the land was porous or cavernous, or where the coast was much broken.** He instances the Hellespontine territory, Achaia, Sicily, and Eubœa, where the sea appeared to flow into narrow passages under the earth.††

It has been stated already that Aristotle's views on the natural motions of the elements, fire, air, water, and earth sometimes caused him trouble when he attempted to show that his explanations were in agreement with the phenomena he tried to explain. His explanation of the phenomena of tempests, thunder, and lightning serves as an example. In some difficult passages in *Meteorol.* ii. c. 9, ss. 2 and 3, he

* *Meteorol.* ii. c. 8, s. 1.
† *Ibid.* ii. c. 8, s. 3.
‡ *Ibid.* ii. c. 8, s. 4.
§ *Ibid.* ii. c. 8, ss. 18 and 19.
‖ *Ibid.* ii. c. 8, ss. 11 and 12.
¶ *Ibid.* ii. c. 8, s. 6.
** *Ibid.* ii. c. 8, s. 8.
†† *Ibid.* ii. c. 8, s. 9.

seems to say that, during the formation of a cloud by the coming together of the ascending vaporous and dry exhalations, the upper part of the cloud, being cooled more rapidly than the rest, is thicker or heavier. Wherefore, he concludes, thunderbolts, lightning, and tempests, and everything of this kind, travel downwards, although heat naturally travels upwards.* Whatever amount of the dry exhalation, he says, is enclosed within the clouds, during the process of ascent and cooling, is separated when the clouds meet and, being carried along and striking violently against neighbouring clouds, this exhalation gives rise to a shock, the noise of which is called thunder.† Aristotle proceeds to say that the *spirituous vapour* itself, which has thus been pressed out or separated, is generally burnt with a slight or weak burning and is what is called lightning.‡ Here again he fails to appreciate the intensely hot nature of a white-hot body, compared with that of a red-hot body. Aristotle concluded that lightning was produced after both the shock and the accompanying thunder. He correctly states, however, that the lightning is seen before the thunder is heard, because sight is quicker than hearing, just as can be seen in the rowing of triremes, for at the moment when the oars are raised the sound of the preceding splash of the oars is heard.§

Aristotle sums up his views on the causes of winds, earthquakes, lightning, and thunder towards the end of *Meteorol.* ii. c. 9, where he says that they are all essentially the same, *viz.*, a dry exhalation which produces earthquakes when operating within the Earth, winds when operating about the surface of the Earth, and lightning and thunder when operating among the clouds.‖

He discusses at great length the saltness of the sea. Some philosophers, he says, believed that the sea was produced originally in the following manner :—The whole space about the earth was water which, being dried by the heat of the Sun, gave off vapours from which winds were generated, the residual water forming the sea. They believed, therefore, that the sea was becoming less and less, and would ultimately become quite dry. They were led to this conclusion, according to Aristotle, by observing that many places were drier in their time than they formerly were.¶ He treats with contempt the opinion of Empedocles and

* *Meteorol.* ii. c. 9, s. 4.
† *Ibid.* ii. c. 9, s. 5.
‡ *Ibid.* ii. c. 9, s. 8.
§ *Ibid.* ii. c. 9, s. 9.
‖ *Ibid.* ii. c. 9, s. 21.
¶ *Ibid.* ii. c. 1, s. 3, ii. c. 3, s. 7.

others that the sea is a sweat of the Earth, resulting from the heating of the Earth by the Sun.* Some said, according to Aristotle, that, just as water percolating through ashes becomes salt, so in the same way the sea was salt in consequence of a mixture therewith of earthy substances.† They were of opinion that rivers flowing into the sea carried into it many earthy substances having various flavours, and, by mingling with the sea-water, caused it to be salt.‡ This explanation was rejected by Aristotle on the ground that, if it were true, the rivers ought to be salt.§

When giving his own views explaining why the sea is salt and why it remains so, Aristotle shows very clearly that he was aware of the vast amount of evaporation due to the solar heat, that it was fresh water which was thus raised into the atmosphere, the salt water being left behind, and that all this fresh water ultimately condensed and descended to the earth or the sea. He knew also that the quantity which descended varied in different places and at different seasons, but he clearly asserts that, during certain definite periods, all the evaporated water descended again.‖

After making many other statements, many of which are uninteresting or apparently valueless, he says that, with respect to the cause of the saltness of the sea, it is clear from many indications that such saltness is due to a mixture of something with the water.¶ Among the indications which he gives, the following are worth reciting:—(1) water which has percolated through the walls of a completely closed wax vessel, immersed in the sea, is found to be fresh or potable; (2) the thickness or density of sea-water is so much greater than that of river-water that merchant ships, similarly laden, almost sink in the former but float in the latter at a depth convenient for sailing; and (3) eggs, even when full, float in water made very salt by mixing saline substances with it.**

Aristotle, having proceeded so far, might perhaps reasonably have been expected to conclude that the something mixed with the water of the sea was some saline substance, but nowhere does he appear to do so. The substance which he decided was mixed with the water was that peculiar one, the dry exhalation, referred to so often already. He says that some believed that the sea was

* *Meteorol.* ii. c. 1, s. 4, ii. c. 3, s. 12.
† *Ibid.* ii. c. 1, s. 5.
‡ *Ibid.* ii. c. 3, s. 10.
§ *Ibid.*
‖ *Ibid.* ii. c. 2, ss. 12–14.
¶ *Ibid.* ii. c. 3, ss. 22 and 35.
** *Ibid.* ii. c. 3, ss. 35–38.

generated from burnt earth, but that this was absurd, although it was true that the saltness of the sea was produced from something of this kind. His own explanation, which is difficult to follow, seems to be that dry and earthy exhalations were mixed in some way with rains and imparted a saltness to them.* Southerly winds and the first autumnal rains, he says, are especially salt, for the southerly winds blow from dry and hot places and so contain little moisture but a large quantity of the dry exhalation to which the saltness is due.† Aristotle had evidently noticed that winds blowing from Africa and across the sea to Greece were salty near the coast. That this saltness was due to the presence of particles of salt and fine sea spray he does not seem to have known. He considered it rather as a proof of the presence of the dry exhalation to which he decided that the saltness was due. There is a fatal objection to Aristotle's explanation, *viz.*, that, if it were true, the rivers also ought to be salty. Olympiodorus, who wrote a commentary on the *Meteorology*, deals with this objection in a fanciful way, and argues that, in order that a mingling of the exhalation with water may take place, the water ought to be at rest and not constantly flowing like that of rivers, and, furthermore, that the exhalation always tends towards the sea, which is lower than the rivers.‡

Aristotle's views, or modifications of them, were generally accepted until the middle of the seventeenth century. Boyle says that the Aristotelians of his time derived the saltness of the sea from the strong action of the sun's rays on the water, and he also says: "But some of the champions of Aristotle's opinion are so bold as to allege experience for it, vouching the testimony of Scaliger to prove that the sea tastes salter at the top than at the bottom, where the water is affirmed to be fresh.§ The Aristotelians thus misrepresented Aristotle, who distinctly asserts, in *Meteorol.* ii. c. 2, that the salt water sinks because of its heaviness, while fresh water is borne upwards. Theophrastus did not accept Aristotle's explanation, for, according to Olympiodorus,‖ he believed that the saltness of the sea was due to exhalations from the earthy bed of the sea.

When dealing with the phenomena of relative changes

* *Meteorol.* ii. c. 3, ss. 24 and 25. † *Ibid.* ii. c. 3, ss. 26 and 27.
‡ *In Meteora Arist. Comment.*, edit. J. B. Camotius, Venice, 1567, p. 61.
§ *The Works of the Honourable Robert Boyle*, new edition, London, 1772, vol. iii. p. 765. ‖ *Op. cit.* p. 60.

of land and sea Aristotle dissents from those philosophers who believed that such changes were due to a continuous diminution of the sea or to changes of the Kosmos. It would be absurd, he says, to move the Kosmos for the sake of what are, after all, only small and temporary changes. They also say, he asserts, that the sea becomes less, in consequence of its being in process of drying up, for more places appear to be dry than there used to be, but if they had extended the range of their observations, they would have found that, in some cases, the sea had encroached on the land.*

It should be considered, he says, that these relative changes of land and sea take place in some kind of order and according to a kind of cycle, and that, just like plants and animals, the inner parts of the Earth have their prime and decay, with this difference that, while a plant or animal, as a whole, has its prime and old age, the Earth itself has not, but only its parts.† He decided that the relative changes took place through the occurrence, during a very long period, of seasons of excessive rainfall, just as, in Greece, winter with its heavy rains occurred yearly, but these supposed seasons of excessive rainfall did not always happen in the same regions, and might be quite local, just as the deluge of Deucalion took place chiefly about Dodona and the region of the Achelous.‡ Such periodical increase in the rainfall and, consequently, in the quantity of water flowing into the sea, caused the sea to encroach on the land, while a diminution of rainfall resulted in a retirement of the sea. He does not suggest that the relative changes of land and sea were due to movements of the land, although he gives instances of some of the effects of earthquakes.

Aristotle proceeds to show, in several eloquent passages, that these changes were part of the ordinary course of Nature. The Kosmos, he says, is indestructible and yet undergoes changes, so that it follows that the same parts of the Earth will not always be land or always covered by seas or rivers.§ Events prove this, for the whole country of the Egyptians seems to be the work of the Nile, and Lake Mæotis [Sea of Azov] is in process of being silted up.‖ "It is evident, therefore, since Time fails not and the Universe is eternal, that neither the river Tanais nor the Nile has

* *Meteorol.* i. c. 14, ss. 17–19.
† *Ibid.* i. c. 14, ss. 2 and 3.
‡ *Ibid.* i. c. 14, ss. 20–22.
§ *Ibid.* i. c. 14, s. 25.
‖ *Ibid.* i. c. 14, ss. 26 and 29.

always flowed, but there was a time when the places where they flow were dry, for their work has an end but Time has none."* He concludes that rivers are produced and destroyed, that the same regions of the Earth are not always the same, land or sea, as the case may be, and that everything changes in course of time.†

In *Meteorol.* iii. c. 7, Aristotle treats of materials found beneath the surface of the Earth. He says that, just as there are two exhalations, the vaporous and the dry or smoke-like, so also there are two kinds of substances in the Earth itself. The first kind includes those substances which are merely dug out of the Earth and have been formed as a result of "complete burning" of the dry exhalation, *e.g.*, infusible kinds of stones and realgar, red and yellow ochres, sulphur, and the like; substances of this kind are generally stones or coloured powders. The second kind includes those obtained by regular mining operations, and are produced, in some way, from the vaporous exhalation, *e.g.*, fusible or malleable substances, like gold, iron, and bronze.‡ By iron and bronze, Aristotle clearly means the ores from which this metal and alloy are respectively obtained; in *Meteorol.* iv. c. 6, he incidentally gives some account, to be discussed later, of iron and its conversion into steel.

The distinction made between the different kinds of mineral substances, in *Meteorol.* iii. c. 7, is almost equivalent to the recognition of a class of ores and another of metals. Aristotle's coloured powders or pigments include some ores, *e.g.*, the ochres include oxide of iron and red lead, and realgar (red sulphide of arsenic, the *Sandarache* of the ancient Greeks) is an ore of arsenic. All these pigments were well known to the ancient Greeks.

Aristotle attempts to explain the production of gold and other metallic deposits in the earth. His explanation is by no means clear, but he seems to mean that the vaporous exhalation, enclosed more particularly in rocks, is compressed and solidified and appears as a separate body, like dew or hoar-frost. The metallic substances exist before the condensation takes place. All, except gold, can be affected by the action of fire and contain earth, for they contain a dry exhalation.§ This shows, as far as it can be understood, that he believed that the vaporous exhalations from which

* *Meteorol.* i. c. 14, s. 31.
† *Ibid.* i c. 14, s. 32.
‡ *Ibid.* iii. c. 7.
§ *Ibid.* iii. c. 7.

metalliferous substances, except gold, are produced, contain some earthy substance. Aristotle's explanation of the production of metallic substances does not show how the gold, &c., was supposed to exist in the vaporous exhalation, but his explanation resembles, in a crude way, one of the modern views of the formation of metalliferous veins by the deposition of metalliferous substances from very hot steam ascending through fissures in the crust of the Earth.

At the end of *Meteorol.* iii. c. 7, Aristotle says that each kind of mineral substance should be described separately. It is said that the alchemists used to refer to a work dealing with the transmutation of metals, and that they assigned this work to Aristotle. It seems to be very unlikely that Aristotle wrote a separate work on metals or mineral substances. There appears to be nothing in Olympiodorus to show that such a work was written. Theophrastus wrote a separate work, entitled *On Stones*, in which he practically accepts Aristotle's division of mineral substances and their production from exhalations, but the rest of the work suggests very little that can be traced to Aristotle, who, moreover, is not even mentioned by name.

Having described Aristotle's explanations of many celestial, atmospheric, and terrestrial phenomena, it remains to describe the most interesting parts of his work on these phenomena, *viz.*, his numerous records of the phenomena themselves. In what follows, the records of celestial phenomena will be described first, then the records of atmospheric, and, finally, those of terrestrial phenomena.

In the year B.C. 373, Aristotle saw a great comet which appeared in the west on a clear, frosty evening in winter, when Aristæus [Asteus] was archon. It set before the sun on the first evening, but was well seen on the next evening, although it set quickly. Its tail extended as far as the Belt of Orion, and there faded away. This tail appeared as a well-defined track, whence it was called a "road."*

According to von Humboldt,† this comet was believed by von Boguslawski to have been the same as the comets of 1843, 1695, 1548, and 1401, with a period of one hundred and forty-seven years. Von Boguslawski, in fact, called that of 1843 the Comet of Aristotle, which he traced back to the year B.C. 371. It may be mentioned that the comet of 1843 was very brilliant.

* *Meteorol.* i. c. 6, ss. 8 and 10.

† *Cosmos*, Bohn's Library, 1849–1858, vol. ii. p. 526, and vol. iv. p. 541.

When Eucleus, son of Molon, was archon, a comet appeared towards the north, during the early part of January.* The date of appearance of this comet is believed to have been about B.C. 350.

Aristotle also says that, when Nicomachus was archon, a comet was seen for a few days, that it appeared about the Equator, and that it did not rise in the evening.† The date of appearance of this comet is believed to have been B.C. 340.

In *De Cœlo*, ii. c. 12, 292*a*, Aristotle says that he had seen the Moon, when half-full, pass under Mars, which was hidden by the dark part of the Moon, and then emerged from the bright part. This occultation of Mars by the Moon occurred, according to Kepler's reckoning, in B.C. 357.

In B.C. 467 a large stone is said to have fallen at Ægospotamos. This meteoric stone is mentioned in the Parian Chronicle. Aristotle says that this stone fell by day, and that in the evening of that day a comet appeared. He incorrectly states that the stone had been raised by the wind and then fell down.‡

He mentions, as an instance of a rare phenomenon, that in the region of the Bosphorus two parhelia rose together with the sun and continued to be seen until sunset.§ Ideler makes a reasonable suggestion to explain how such a report arose, saying that the ancient Greeks used to relate extraordinary phenomena as taking place in the Bosphorus, Black Sea, and Africa, just as modern writers have given accounts of extraordinary phenomena in America and Siberia.‖

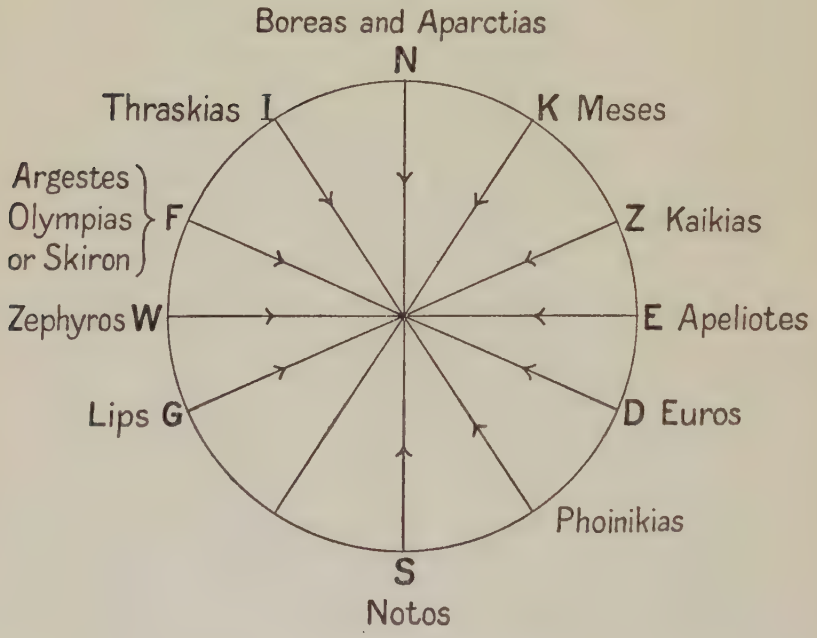
Aristotle gives some interesting information about some of the periodic winds of Greece. The Etesian winds, he says, blow from the north after the summer solstice and the rising of the Dog Star, and they blow by day but cease at night.¶ Some were at a loss to understand why the Etesians, continuous north winds, blew after the summer solstice, while south winds were not produced similarly after the winter solstice, but this, he says, is not reasonable, for the so-called Leuconoti, although they do not blow continuously, blow at the season of the year opposite to that at which the Etesians blow.** Early in spring, according to Aristotle, the Ornithiæ blow; these winds are gentler than

* *Meteorol.* i. c. 6, s. 8.
† *Ibid.* i. c. 7, s. 10.
‡ *Ibid.* i c. 7, s. 9.
§ *Ibid.* iii. c. 2, s. 6.
‖ *Aristot. Meteorol.*, Leipzig, 1836, vol. ii. pp. 271, 272.
¶ *Meteorol.* ii. c. 5, ss. 5 and 7.
** *Ibid.* ii. c. 5, s. 7.

the Etesians, and do not blow continuously.* These winds were called Ornithiæ because they blew when birds were mating, or because migratory birds arrived with them in Greece.

In *Meteorol.* ii. c. 6, Aristotle gives directions for drawing a diagram showing the quarters from which the chief and

FIG. 3.



ARISTOTLE'S COMPASS.

best defined winds blew. Fig. 3 has been drawn according to these directions, Z being the position of the rising sun in midsummer, F that of the setting sun in midsummer, D that of the rising sun in midwinter, and G that of the setting sun in midwinter. I is half-way between due north and F, and K is half-way between due north and Z. Athens is supposed

* *Meteorol.* ii. c. 5, s. 9.

to be at the centre of the circle. The names of the winds are indicated on the drawing. Aristotle says that the wind called Meses had no wind diametrically opposite to it, nor had the wind Thraskias, unless a certain wind, called Phoinikias, were considered to be its opposite. This wind was so called because it was believed to blow from Phœnicia.

An account of the nature of these winds is also given by Aristotle. He says that Lips, Kaikias, and Apeliotes were wet winds, while Euros was dry at first but ultimately became wet. Kaikias and, to a less extent, Lips were associated with a cloudy sky. Argestes was a dry wind. Meses and Aparctias were very cold winds and brought a great deal of snow, and there was much lightning when Meses was blowing. Aparctias, Thraskias, and Argestes blew when the sky was clear, but brought hail, lightning, and gales. Finally, Notos, Zephyros, and Euros were hot winds.*

During most of the hot or dry season, in many parts of Greece, northerly winds, called Etesians, blow by day until about sunset, when winds set in from an opposite direction, and, at Corinth, there is an alternation of easterly and westerly winds which is so regular that Strabo compared it to the breathing of an animal. The idea that a wind blowing in one direction has a counterpart in one blowing in an opposite direction is, therefore, natural to a Greek, but Aristotle seems to carry this idea further than is true for any one locality. My knowledge of the meteorology of Greece, derived chiefly from Reclus, modern books of travels, and notes sent me by Mr. W. R. Halliday, from the British School at Athens, is not sufficient to enable me to discuss fully Aristotle's numerous statements about the winds and weather of Greece.

The northerly winds of Greece are usually very dry and the southerly winds wet. The Sirokos or Scirocco, which seems to be the same as the ancient Euros, is a S.E. wind, moist, hot and oppressive. Another oppressive wind is the Austral, which blows from the south and may be Aristotle's Notos. In the Cyclades, steady north winds usually make the early months of the year cold,† and Mr. Halliday says that at Melos certainly Boreas prevailed until well after the Greek Easter this year (1911). Aristotle says that Zephyros is a hot wind. In his note Mr. Halliday says :—"Just lately [early part of June, 1911] I have been suffering from

* *Meteorol.* ii. c. 6, ss. 19–22. † Bent's *Cyclades*, p. 57.

the west wind, not only unpleasantly hot but also apparently possessed of the property of rousing insect life to activity. At least, the common house fly drew blood through my thick stockings, and when I complained I was told that it was due to the wind."

Aristotle makes assertions, some of which were evidently mere guesses, about the depths of various seas. He says that the Pontus is deeper than the Mæotis (now called the Sea of Azov), that the Ægean is deeper than the Pontus, that the Sicilian is deeper than the Ægean, that the Sardonic and Tyrrhenian seas are deeper than any of these, and that the waters beyond the Pillars of Hercules are of small volume because of the mud, and are undisturbed by winds.*

The Sea of Azov is said to be not deeper than eight fathoms, and has long been known to be very shallow. Aristotle says that it had been silted up to such an extent that the ships which sailed on it in his time were much smaller than those which sailed on it sixty years before.† The silting-up process still goes on and Aristotle's statement is probably correct. I do not know whether the Ægean is deeper than the Pontus or Black Sea, but Aristotle correctly states that the Sicilian, by which he probably meant the sea between Sicily, Greece, and Crete, is deeper than the Ægean. Respecting the other seas mentioned by him, his statements are incorrect. Comparatively recent soundings show that, although the average depth of the eastern Mediterranean is only a few fathoms greater than that of the western Mediterranean, yet the maximum recorded sounding in the former is about four hundred fathoms greater than the maximum recorded sounding in the latter. The maximum sounding in the eastern Mediterranean is not less than two thousand four hundred fathoms, to the S.W. of Cape Matapan and therefore in a part of Aristotle's Sicilian Sea. His statement about the waters beyond the Pillars of Hercules is obviously derived from the famous legend of a sunken Atlantis, related by Plato in the Timæus, and needs no further comment. When arguing that sea water contains a large quantity of earthy matters to which the saltness and bitterness of the water are due, Aristotle refers to the Dead Sea, saying that if, according to the tales which some narrate, there is a lake in Palestine of such a kind that a

* *Meteorol.* ii. c. 1, ss. 13 and 14. † *Ibid.* i. c. 14, s. 29.

man or beast of burden would not sink beneath its waters, then this would be evidence for what he had said, and he adds that, according to report, the waters of the lake are so sharp and bitter that no fishes are found in them, and that, by merely dipping clothes into its waters and then shaking them, the clothes are washed.* These reports, which he was evidently reluctant to believe, were much more reliable than he thought them to be.

In Chaonia, Aristotle says, a spring of rather salt water rises and flows into a neighbouring river.† References are also made to streams of acid water in the Sicanian territory of Sicily, and near Lyncus, and to bitter waters in Scythia; Aristotle also says that, from the waters of Sicania, a sauce was made and used just like vinegar. ‡

Chaonia was a large district in Epirus, extending from the Acroceraunian promontory on the north towards the Acheron on the south. The spring to which Aristotle refers may be a source of the river Cocytus, a tributary of the Acheron. The modern name of the Cocytus is Vuvó, the waters of which are said to be unfit for drinking purposes. Sicania was the district about Agrigentum in the south of Sicily, and in this part of the island there are many salt springs, the waters from which flow into the Platini and Fiume Salso, which are the modern representatives of the ancient rivers Halycus and Himera, respectively. Lyncus was in Lyncestis, a district of Macedonia near the Illyrian frontier. At or near the modern Bánitza are the acid waters of Lyncus, which were said to have had intoxicating qualities.§ It is impossible to identify the bitter waters of Scythia, referred to by Aristotle. Scythia was a territory of vast extent, including most of southern Russia, and its boundaries were indefinite and changed from time to time.

In his *Meteorol.* i. c. 13, Aristotle gives an interesting account of the chief mountains, rivers, lakes, and seas of the ancient World, and this account represents probably all that was best of the geographical knowledge of his time. His own travels were confined mainly, and perhaps entirely, to southern Macedonia, Attica, Eubœa, Lesbos, and Mysia, and he was dependent, therefore, on those who, like Hecatæus and Herodotus, had visited many lands. The World which he describes extended from the Hindoo Koosh and the Indus

* *Meteorol.* ii. c. 3, s. 39.
† *Ibid.* ii. c. 3, s. 40.
‡ *Ibid.* ii. c. 3, ss. 46 and 47.
§ Smith's *Dict. of Classic. Geogr.*

on the east to the Atlantic on the west, and from the northern parts of Europe on the north to the sources of the Nile on the south. In whatever direction his ancient World is traced, it may be said to be distorted in proportion to its distance from Athens.

He had an exaggerated idea of the height of the Hindoo Koosh or Paropamisus Mountains, which he called the Parnasos, for he says that the apparently boundless ocean could be seen from them. Certain large rivers, he says, flow from them, *e.g.*, the Bactrus, Choaspes, Indus, and Araxes, by which he seems to mean the Oxus. The largest of these, he says, is the Indus. He gives no indication that he had any knowledge of the Ganges. He knew that the Tanais, now called the Don, flows into the Sea of Azov, but his knowledge of that river was very imperfect, for he believed that it was connected with the Araxes.

His description of the regions of the Caucasus is picturesque and interesting. He speaks of the massiveness and great height of the mountains, the many races living among them, and the large lakes of the Caucasus regions. His ideas about the height of the Caucasus Mountains were greatly exaggerated, for he says that their summits could be seen illuminated by the sun for a third part of the night, both before sunrise and after sunset.

Passing to the west of his ancient World, he states incorrectly that the Danube rises in the Pyrenees, and he also says that the Tartessus, beyond the Pillars of Hercules, rises in the Pyrenees. This river cannot be identified satisfactorily, but it is probable that the Guadalquiver is meant, or it may be the Guadiana or the Tagus, not one of which, however, rises in the Pyrenees.

In the north, he says, many rivers flow from the Arcynian Mountains, which are the most massive and highest mountains in that region. He seems to have been the first to mention those mountains, which are usually considered to be the Harz and the Erzgebirge, but Aristotle's Arcynian Mountains probably included the Alps also. He speaks also of the so-called Rhipæan Mountains, of vast size, and situated beyond the farthest parts of Scythia. Aristotle's description of the Rhipæan Mountains would apply fairly well to the Ural Mountains, but J. Barthélemy Saint-Hilaire says that they were perhaps the Carpathians.

In the south of his ancient World, he mentions several large African rivers, the Ægon, Nyses, and Chremetes,

which cannot be identified, and states that the Nile rises in the so-called Silver Mountains.

The question of the position of the source of the Nile was discussed by many of the ancient writers, especially Hecatæus, Herodotus, Hipparchus, and Ptolemy, and it came to be believed that it lay among the so-called Mountains of the Moon, the locality of which was shifted from time to time, until Stanley identified them with the great Ruwenzori Mountains, westwards of the Victoria Nyanza.

After referring to several well-known rivers of Greece, Macedonia, and Thrace, and to streams in Arcadia which disappeared underground, Aristotle gives some interesting information about the Caspian Sea. He says that, at the foot of the Caucasus, is a lake which the people near it call a sea, that it has no evident outlet, and that it empties itself underground at Coraxi into the Black Sea, near the so-called "deeps," which had not been fathomed. Here, according to him, at a distance of about thirty-five miles from land, the sea yields fresh water in three places.

It is evident that Aristotle understood that the Caspian was a large inland sea. After the campaigns of Alexander, many believed that it communicated with an ocean to the north, and von Humboldt, commenting on this view, says that, fortunately, Aristotle wrote his *Meteorology* before those campaigns, for the Macedonian expedition gave rise to some errors which long held their ground.*

Respecting the belief, expressed by Aristotle, about an underground connection between the Caspian and the Black Sea, some interesting information is given by Reclus. According to him, navigators of the Caspian and the Turkoman nomads who wander on its shores have been astonished at the river of salt water which constantly flows through a narrow channel into the Karaboghaz, which forms a kind of inland sea, on its eastern side. In the view of the natives this inland sea could be nothing but an abyss, a "black gulf," as is expressed by the name Karaboghaz, into which the waters of the Caspian dive down in order to flow by subterranean channels into the Persian Gulf or the Black Sea. It is, perhaps, to some vague rumours, Reclus says, as to the existence of the Karaboghaz that we must attribute the statement of Aristotle about the strange gulfs in the Black Sea in which the waters of the Caspian bubble up after their

* *Cosmos*, Bohn's Library, vol. ii. p. 560.

long subterranean passage.* The "deeps" referred to by Aristotle are in a deep part of the Black Sea, but the deepest part of this sea is said to be near its centre. It may be mentioned that Herodotus clearly states that the Caspian is a sea by itself, having no communication with any other.†

The above information given by Aristotle about the mountains, rivers, lakes, and seas of his ancient World is from his *Meteorol.* i. c. 13. In his *History of Animals* he gives some interesting information about the reported land of the Pigmies. He says that such a race, dwelling in caves, actually existed in the upper regions of the Nile, and that cranes migrated from Scythia to the marshy parts of those regions.‡

Many ancient writers refer to the Pigmies of inner Africa, and Herodotus says that the Nasamonian explorers were captured by them and carried across extensive marshes to a city near a river running east and west, and containing many crocodiles.§ It was in the region of the Ituri River, which exactly answers to this description, that Stanley found a race of Pigmies.

A great deal of interesting information is given by Aristotle about changes produced on the Earth's surface by various natural agents. These changes include those caused by the deposition of mud from rivers, the drying up or the formation of swamps, and the destructive effects of volcanic eruptions and earthquakes.

His description of the silting up of the Sea of Azov has been discussed in another part of this chapter. Referring to the Nile delta, he says that all the arms, except the Canobic, were made artificially. Egypt itself he considers was made habitable by the drying up of the swampy parts formed by the deposition of mud in a sea continuous with the Red Sea, and he believed that the whole country of the Egyptians was the work of the Nile. He states incorrectly that the Red Sea was higher than the land about the Nile, and says that Sesostris and also Darius, who tried to connect the Nile with the Red Sea by excavating a channel, found this out and, in consequence, stopped the work of excavation.‖

He says that some places have acquired a more favourable climate through the drying up of swampy parts, while

* *Nouvelle Geographie Universelle*, vol. 6, 1881, pp. 422–24. † i. 203.
‡ *H. A.* viii. c. 14, s. 2. § ii. c. 32.
‖ *Meteorol.* i. c. 14, ss. 10–12 and 26–28.

others have suffered through being dried up too much. This happened, he adds, in Greece, for, about the time of the Trojan War, Argos was swampy and could support only a small population, while Mycenæ was prosperous, but now it is the other way about, for Mycenæ has become quite parched, while the lands at Argos, which were formerly useless because of their swampiness, are now cultivated.*

Aristotle records and makes interesting observations about several great earthquakes and volcanic eruptions. There was, he says, an earthquake in Achaia and an inflow of the sea about the time of the great comet, which was seen during the archonship of Asteus.† Just lately, he says, an earthquake took place at Heraclea, in Pontus, and, some time before this, another occurred in the Sacred Isle, one of the Æolian Islands. Here, a part of the ground swelled up and rose into a hillock, the swelling up being accompanied by a great noise, until the hillock burst and a great quantity of a spirituous vapour (πνεῦμα) issued forth, carrying with it both sparks and ashes. The capital of the Liparæans, not far away, was completely burnt, and the ashes reached some of the cities of Italy. Even now, he says, it can be seen where this eruption took place.‡ It was from observations on eruptions such as this that Aristotle concluded that earthquakes and volcanic eruptions were due to a violent circulation within, and final discharge from, the interior of the Earth of a kind of air, gas, or vapour, which he calls "wind" (ἄνεμος) in some passages and "spirituous vapour" (πνεῦμα) in others.

When the spirituous vapour is abundant, he says, a lateral tremor of the earth takes place, or, occasionally, a vertical pulsation. In this kind of earthquake a large quantity of stones comes to the surface, just like anything which rises to the top in a winnowing-fan. The parts about Sipylus, the Phlegræan Plain, and the Lygian region were overturned by earthquakes of this kind.§

He asserts that islands in a deep sea are less liable to earthquakes than those situated near land, because of the cooling and restraining effect of so large a quantity of sea-water on the spirituous vapours or exhalations, and because the islands could not be disturbed without the necessity of moving the whole of the sea surrounding the islands.‖

* *Meteorol.* i. c. 14, ss. 14 and 15. † *Ibid.* i. c. 6, s. 8.
‡ *Ibid.* ii. c. 8, ss. 18 and 19. § *Ibid.* ii. c. 8, ss. 46 and 47.
‖ *Ibid.* ii. c. 8, ss. 48 and 49.

Aristotle's seismic records are among the best made by ancient writers. Heraclea Pontica, referred to by him, was a Greek colony on the western part of the coast of Bithynia. The Lipari Isles were repeatedly affected by seismic disturbances in ancient, just as in modern, times, but the one recorded by Aristotle was more than usually destructive. His description is vivid and interesting, and seems to refer to a great eruption of a viscous lava. The eruption seems to have been similar in many respects to that in the trachytic district of Methana, described by Strabo. At Methana, a hill nearly a mile in height was raised up, and the force of the eruption was so great that blocks of stone as large as towers were ejected.* The earthquake at Sipylus, situated in a mountain of that name in Lydia, was long remembered by the Ancients, for Sipylus is said to have been totally destroyed.

Aristotle's record of an earthquake in the Lygian region is not clear. Von Humboldt says that the region referred to is now called La Crau, at the mouth of the Rhone, and that the rounded quartz blocks of that region were supposed by Aristotle to have been ejected from a fissure, during an earthquake.†

Besides the phenomena already discussed, Aristotle incidently refers to several matters of minor importance, such as, for example, the weight of air and the existence of red snow.

In his *De Cœlo*, iv. c. 4, 311*b*, he says that a bladder, when inflated, is heavier than when it is empty. This passage suggests that Aristotle actually tried the experiment, but this is all that can be said, for he gives no further information.

Red snow was known to him, for, in *H. A.* v. c. 17, s. 12, he says that animals are produced in some things which seem least liable to putrefaction, such as snow which has lain for a long time ; such snow, he adds, is reddish, and, for this reason, the larvæ of the animals in the snow are red and hairy.

The snow to which Aristotle refers was probably seen by him in Macedonia. The redness of snow is caused, as is well-known, by the presence of red unicellular plants, *Protococcus nivalis*. It will be noticed that Aristotle did not consider that the colour of the snow was due to the colour of the animals which he believed were present, but that the colour of these was due to the redness of the snow.

* *Geogr.* i. c. 3, s. 18. † *Cosmos*, Bohn's Library, vol. i. p. 102.

CHAPTER IV.

PHENOMENA OF LIGHT AND COLOUR, HEAT AND SOUND.

It is said that, after Aristotle had published a work on some esoteric part of his philosophy, Alexander the Great wrote to him from Asia complaining of his attempting thus to communicate to people generally what had previously been imparted to Aristotle's select pupils only. Aristotle replied to the effect that no harm could be done by the publication complained of, because what he had put forth in his lectures on the more abstruse parts of his philosophy could be understood only by those who heard him and by nobody else. The work referred to is considered by some to have been Aristotle's *Akroasis Physike*, commonly called the *Physics*. The above story may or may not be true, but it is undeniable that many parts of Aristotle's works on essentially abstruse subjects are very difficult to understand, and among such parts are those relating to light and colour.

The history of the development of this branch of human knowledge reveals, it is true, many great achievements, but it probably reveals many more disappointing failures, and little of any practical importance was done until about the twelfth century. Successful investigation of phenomena of light and colour has been largely the result of careful observation and ingenious experiments, and few, if any, branches of natural science better exemplify a laborious, step by step, advance to the truth. Aristotle's achievements, judged by the standard of knowledge in more modern times, were of little value, although they must have cost him much time and labour, as may be seen from his account of the causes of rainbows, already given in Chapter iii.

The ancient emission or corpuscular theory of light held by Empedocles, Democritus, and many other ancient philosophers was rejected by Aristotle. He says that light is

not fire nor any material substance, nor, consequently, is it an emission from a material substance,* and that the theory that sight is due to something which issues from the eye, and is capable of extending as far as the stars, or, as some say, that it is due to something which issues from the eye and meets with something issuing from the object, is altogether absurd.† Aristotle's own views on the nature of light seem to have been as follows: Something which he calls the *Diaphanous* (τὸ διαφανές) is present not only in air, water, and other transparent substances, but also, in varying degrees, in other bodies. It is not capable of separate existence, being a kind of property and power common to all bodies, and, when excited by the presence in it of something of the nature of fire, light is produced, while the absence of anything of the nature of fire results in darkness.‡ Light is the energy of the *Diaphanous*, and is, as it were, the colour of the *Diaphanous*, when this is in actual or full existence (ἐντελέχεια) through the influence of fire or something of this kind, such as, for example, the upper body.§ The upper body, referred to here, is the Aristotelian æther, which resembles the æther of modern scientists in some respects, but is here supposed by Aristotle to be an exciting cause of light.

The *Diaphanous* was evidently passive, but capable of being influenced by fire or something of the nature of fire. The relationship between fire or the like and the *Diaphanous* seems to be like that between form and material, as exemplified by a stone statue, for, when the *Diaphanous* is modified by the presence of fire or the like, light is produced, while the stone, modified so as to be of a particular form, is a statue.

In an important passage Aristotle says:—"I have stated in other books that sight is impossible without light, but whether it is light or air which intervenes between the object and the eye, it is the motion through this medium that causes sight."‖

This may seem to foreshadow the undulatory theory of light. It seems, however, from other passages that the motion was not an undulatory one, although he nowhere seems to explain what kind of motion he meant. He says that odours and sounds travel through a medium before they cause sensation, and that Empedocles believed that

* *De Anima*, ii. c. 7, 418*b*. † *De Sensu, &c.*, ii. 438*a*. ‡ *Ibid.* iii. 439*a*.
§ *De Anima*, ii. c. 7, 418*b*. ‖ *De Sensu, &c.*, ii. 438*b*.

sunlight had to travel through a medium before it reached the eye, but, about light, he adds, a different account must be given, for light is due to the existence of something in the medium, and is not a motion.* This last statement causes some difficulty, because it seems to be inconsistent with the passage in *De Sensu, &c.*, ii. 438*b*. The word κίνησις, used in *De Sensu, &c.*, vi. 446*b*, is a general one for "motion," and does not give much assistance in ascertaining what Aristotle meant. The context, however, indicates that the meaning is that light is not due to a motion of translation, necessarily taking place during an interval of time. In fact, Aristotle says, in *De Sensu, &c.*, vi. 447*a*, that it is reasonable to believe that, when there is a medium between a sensory organ and an object of sensation, the effects are not all produced on the sensory organ at the same time, except in the case of light and sight.

Aristotle was not the first to introduce the idea of a motion of the medium between the eye and the object seen by it. Democritus believed that the emanations from the object did not reach the eye, but set in motion the intervening air.

Like many other ancient philosophers, Aristotle was aware that light should be treated as if it were propagated in straight lines. Many parts of his descriptions of optical phenomena, *e.g.*, rainbows and eclipses, show this, and some questions are proposed in the Aristotelian work called the *Problems*, the answers to which depend on the assumption that the propagation of light is in straight lines. One of these questions is particularly interesting, and asks why sunlight shining through apertures bounded by straight lines does not form rectilinear images but circular ones. The first part of the answer suggests that it may be that the light is propagated in conical form and, the base of a cone being circular, the images are circular also. Then follows an explanation which is quite Aristotelian, and depends on an assumed inability of visual rays, which are few and weak, to reach the object to be seen; such an assumption is made in other places by Aristotle, particularly in his explanation of rainbows. The rays of light, passing through the corners of the apertures, being assumed to be few and weak, are not effective, but only the rays passing through the central parts, these rays being assumed to be numerous and strong;

* *De Sensu, &c.*, vi. 446*a* and *b*.

the images, therefore, appear to have rounded corners.* This explanation is fanciful, but the one referring to the propagation of light in conical form, although of little value, is suggestive, for the true explanation can be obtained by drawing a series of co-axial double cones with their apices at various points on the sides of the aperture, the Sun's disc and its image being the bases of each double cone. The overlapping of the separate images of the Sun's disc, thus drawn, causes the images formed by the aperture to be circular, if the aperture is small, or to have rounded corners, if the aperture is large.

Aristotle was fully aware that reflection takes place from mirrors and other smooth surfaces. He often uses the word *Anaklasis*, a breaking back or aside, to denote this phenomenon, especially in his descriptions of halos and rainbows. There does not appear to be any passage in his works, however, showing that he was aware of the equality of the angles of incidence and reflection. This seems to have been stated for the first time in Euclid's *Catoptrics*, Prop. i., where the law is enunciated and proved for plane, convex, and concave mirrors.

He does not use the word *Anaklasis* or any other word in such a way as to show that he was acquainted with the phenomenon of refraction, but in *Meteorol.* iii. c. 4 there are some passages which deserve special notice in connection with this question. After speaking about the strange optical illusion in the case of a man whose sight was very weak and who saw an image of himself in consequence of the adjacent air acting like a mirror, Aristotle says :—" Wherefore headlands appear inverted in the sea, everything appears larger when the easterly winds (εὖροι) blow, and also objects seen through mists, *e.g.*, the Sun and stars seem to be larger when rising or setting than when they are high in the heavens."†

Ideler says that these examples, given by Aristotle, pertain not so much to reflection of light as to refraction.‡ This is not so. They pertain mainly to reflection and absorption. The phenomena of absorption were only imperfectly understood by Aristotle, but many statements he makes about light and colour show that he never lost sight of what appeared to be the effects of the medium between

* *Problems*, xv. 6. † *Meteorol.* iii. c. 4, s. 4.
‡ *Aristot. Meteorol.* Leipzig, 1836, vol. ii., p. 20.

the eye and an object of vision. The inversion of headlands in the sea, to which he refers, is probably nothing but that produced by reflection at the surface of the water, and is intended to show how untrustworthy the sight may be, just as in the case of the man who, Aristotle says, saw his own image reflected by the air in front of him.

The observation, that all things seem to be larger when easterly winds blow, may refer to the apparent nearness which is associated with moist atmospheres. According to Aristotle, the easterly winds referred to were hot and, at first, dry, but became moist. I have made enquiries, but have been unable to ascertain whether such a phenomenon occurs at Athens, when easterly winds blow.

Aristotle's reference to the apparent magnification of the sun and stars is correct, but here again the effect is not due to refraction. It is now known that there is no magnification, the result being mainly psychological. Seneca attempts to explain the apparent magnification of the sun and stars by saying that our sight is not reliable in the case of an object seen in water or through a moist medium, for, if a ring is thrown into a bowl filled with water, yet, although the ring lies at the very bottom of the bowl, its image is seen near the top of the water. Whatever, he says, is seen through a liquid or moist medium appears to be far larger than it really is.* It is evident that Seneca, who was well acquainted with Aristotle's works, did not understand the phenomena of refraction. He developed Aristotle's idea that the apparent magnification was due to weak sight, or sight under unusual conditions, the nature of which Aristotle himself does not explain.

The knowledge of the Ancients about refraction was of very slow growth. Some of them made observations on this subject, for Archimedes is said to have written a book on the appearance of a ring seen in water, and Seneca refers to the broken appearance of an oar dipped in water,† the magnification of letters seen through a glass globe filled with water, and the fairer appearance of apples seen floating in water in a glass vessel.‡ Neglecting the work on Optics, probably wrongly assigned to Ptolemy, containing many interesting observations on the refraction of light by glass, water, and air, no important advance was made in the study

* *Nat. Quæst.* i. c. 6, ss. 5 and 6. † *Ibid.* i. c. 3, s. 9.
‡ *Ibid.* i. c. 6, s. 5.

of refraction until about the year A.D. 1100, when Alhazen attempted to determine the relation between the angles of incidence and refraction, and set out some of the laws of refraction.*

Aristotle was acquainted with the phenomenon now called phosphorescence, but did not understand it. He says that it is the nature of smooth surfaces to shine in the dark, but yet they do not produce light.† Again, he says that some objects are seen in the dark, *e.g.*, those which seem to be of the nature of fire and shining, such as, for example, fungi, horn, sepia juice, and the heads, scales, and eyes of fishes, and that these do not show the proper colours of the objects themselves.‡

It is not clear what is meant by the assertion that light (φῶς) is not produced by objects shining in the dark. If Aristotle had said that heat is not produced, he would have made a substantially true statement, but light is produced and some phosphorescent bodies emit a light as brilliant as that given out by firebrick or other ordinary substances heated to a high temperature. It is clear, from the passage in *De Anima*, ii. c. 7, cited above, that Aristotle did not consider phosphorescent bodies to be actually of the nature of fire, in which case they would emit heat, like a flame or incandescent body, and this may be a reason why he states that no light is emitted, since no heat accompanies the shining effects. That a phosphorescent body does not shine with a colour like that of the body itself, as Aristotle says, is true, *e.g.*, the white flesh of fishes often shines with a delicate green light.

Difficult though it is to follow Aristotle's speculations on light, it is more difficult to follow his speculations on colour. It has been stated already that, according to him, the *Diaphanous* exists in varying degrees in all bodies. He defines the colour of a body to be the boundary of the *Diaphanous* which is in the body.§ Whatever the nature of the *Diaphanous* may be, it cannot exist separately, Aristotle says, but has limits to the same extent as the bodies in which it exists. Light exists in the *Diaphanous*, but, if a particular body be considered, it is evident that the

* *Opticæ Thesaurus Alhazeni Arabis*, F. Risnerus, Basle, 1572, Book vii., especially c. 3, entitled "De qualitate refractionis lucis in corporibus diaphanis."

† *De Sensu, &c.*, ii. 437*a*.

‡ *De Anima*, ii. c. 7, 419*a*; *De Sensu, &c.*, ii. 437*b*.

§ *De Sensu, &c.*, iii. 439*a* and *b*.

boundary of the *Diaphanous* which is in it is something real. The phenomena show clearly, he says, that this is colour, for colour either is in the boundary or is the boundary, wherefore the Pythagoreans considered the external surface of a body to be the same as its colour. Aristotle proceeds to say that colour is not the boundary of the body itself, but is in the boundary, and that the nature or constitution of the inner parts of the body is the same as that which, at the surface of the body, constitutes colour.* Again, he says that colour is continuous with light,† and, as has been stated already, he considers light to be the colour of the *Diaphanous*.

It will be noticed that the above statements are of the nature of definitions which give very little assistance in determining how colour effects are produced. The *Diaphanous*, on which all Aristotle's conceptions about colour seem to depend, was a mental conception, or, if intended to be something concrete, its nature is difficult to understand. The boundary of the *Diaphanous* in a body is, however, treated by him as if it were something real, in which the colour of the body existed. According to such views, the green colour of an emerald or the yellow colour of an ingot of gold is manifested only by the external surface of the *Diaphanous* in the emerald or ingot, but the same colour would be manifested by any other section of the *Diaphanous* in these bodies if, by breaking the emerald or cutting the ingot, such section coincided with the plane of breaking or cutting. However difficult it is to understand some of his statements about colour, it seems to be quite clear that he considered it to be a boundary phenomenon.

Both air and water, he says, have a colour of some kind, but, inasmuch as air and water have no definite or fixed boundaries, their colours vary according to the distance from which they are seen. The colours of solid bodies, on the other hand, remain the same, unless the action of anything surrounding or near them causes a change.‡ The last clause of this passage is one of the few assertions to be found in Aristotle's works which suggest that he considered the colour of a body to depend on anything but the nature of the *Diaphanous*. There seems to be nothing to anticipate, however, the modern view that the colours of bodies are not

* *De Sensu, &c.*, iii. 439*a*. † *Physics*, vii. c. 2, s. 4.
‡ *De Sensu, &c.*, iii. 439*b*.

merely surface phenomena, and that colour, such as the green colour of a leaf or an emerald or the yellow colour of an ingot of gold, is due to a selective action effected on light which is composite.

Another interesting question with which Aristotle deals is that of the mixture of colours, but here again his statements are sometimes unsatisfactory, mainly because it is not clear whether he is dealing with the mixture of pigments or of coloured lights.

It has been stated that, according to Aristotle, light results from the presence in the *Diaphanous* of something of the nature of fire, and darkness ensues when this is absent. In a similar way, he says, white and black are produced, in solid bodies, *i.e.*, they are respectively caused by the presence or absence of something of the nature of fire in the *Diaphanous* of those bodies.* He says that one way of producing various colours is by mixing black and white in various proportions, colours pleasing to the eye, such as light red or dark blue, being produced when the proportions of black to white are in simple ratio, just as in harmonies (συμφωνίαι), and other colours, less pleasing to the eye, when the proportions are not in simple ratio. The black and white are supposed to be so arranged relatively to each other that each is invisible because of the smallness of its parts, but the colour of the resulting mixture is visible.†

Aristotle seems to be referring to a mixture of coloured lights, but his conclusions were probably based almost entirely on a process of abstract reasoning. In his explanation of the colours of the rainbow, discussed in Chapter iii., he attempts to show that, when the visual rays are directed to a distant bright object, this appears to be white, black, or some colour intermediate between these, according to the weakness or strength of the visual rays. This is both unsatisfactory and difficult to understand, but in another part of his explanation of rainbows there is a passage which clearly refers to a mixture of coloured lights. He says that an orange colour is seen between the light red and the greenish yellow, such colour resulting from an overlapping of the two colours mentioned.‡ It is true that an orange colour results from a mixture of greenish yellow and light red lights.

* *De Sensu, &c.*, iii. 439*b*. † *Ibid.* iii. 439*b* and 440*a*.
‡ *Meteorol.* iii. c. 4, s. 26.

Another method of producing various colours, Aristotle says, is by laying on a coat of a bright colour and then laying over this a coat of a different and duller colour, so that the bright colour shines through the other. A modification of this method to which he refers is the production of a red colour when the sun shines through mist or smoke.* He speaks also of painters being in the habit of obtaining some colours by mixing paints, but says that they could not thus obtain red, greenish yellow, or blue, and that these were almost the only ones they could not obtain in this way.† It has been explained in Chapter iii. that this passage suggests that Aristotle probably considered the intermediate colour (*πράσινον*) of the rainbow to be some shade of yellow rather than green.

However unimportant Aristotle's work on the nature and production of colour effects may be considered to be, it must be conceded that he incidentally gives information which materially assists in the identification of many ancient Greek names for colours with the modern names of the colours they were intended to denote. In Homeric and even later times the common ideas about colours were not separated from those about brightness, or, in the case of colours of the eyes, vivacity, and there do not appear to have been many colour-names in use. It will be seen, however, that Aristotle used many colour-names, most of which denoted well-defined colours, but, like many other Greek writers, he sometimes employed the words *μέλαν* and *λευκόν* respectively to indicate merely that an object was dark and bright or light. The four colours of the rainbow mentioned by him have been referred to many times already. A deep brownish red colour, like that of the eggs of the kestrel, is called *ἐρυθρόν*.‡ The ash colour or bluish grey of the crane is *τεφρόν* §; while the somewhat lighter tint of many gulls is *σποδοειδές*.‖ The deep and brilliant blues and greens of the kingfisher were *κυανοῦν* and *χλωρόν* respectively.¶

In his description of the colours of the iris, in *H. A.* i. c. 8, s. 4, Aristotle uses the words *μέλαν*, *αἰγωπόν*, *γλαυκόν*, and *χαροπόν* to denote the colours. It is difficult to determine what these were intended to be. The usual colour of a goat's iris is brownish or yellowish, and this is probably the colour *αἰγωπόν*. *Μέλαν* refers to the darkest colours of the

* *De Sensu, &c.*, iii. 440*a*.
‡ *H. A.* vi. c. 2, s. 2.
‖ *Ibid.* viii. c. 5, s. 7.
† *Meteorol.* iii. c. 2, s. 5.
§ *Ibid.* iii. c. 10, s. 11.
¶ *Ibid.* ix. c. 15, s. 1.

iris, χαροπόν to the darker shades of blue or grey, and γλαυκόν to the lighter shades of these colours. That γλαυκόν refers to the lighter shades is shown by a passage in the *Problems*, xiv. 14, where it is stated that the colour of the iris in those living in the northern parts of the ancient World was γλαυκόν, and that this colour was nearly white.

The words χαροπόν and γλαυκόν were used, at first, without any reference to mere colour, the former meaning glad-eyed, and the latter clear or bright. Aristotle advanced far beyond this stage in the formulation of ideas, and was evidently dealing with colours and even shades of colours. In various parts of his works, especially in those parts relating to birds, he uses many words to denote colours, but, in some cases, it is impossible to determine what these were intended to be, simply because the objects to which he is referring cannot be identified. His colour vocabulary, if it could be completed, would be a long one.

Aristotle's observations on heat phenomena are not altogether unimportant, and some of them are very interesting. They relate chiefly to the effects of heat, the essentially hot or cold nature of bodies, including the determination of what came to be called by Aristotelians the *Primum Frigidum*, the production of heat by friction, the modes of determining roughly the temperatures of different bodies, the consideration of the question whether cold is nothing more than privation of heat, and some questions connected with animal heat.

Of the four Aristotelian *elements* or *forces*, heat and cold are active, and the moist and the dry or solid are passive.* By acting on matter in such a way as to overcome it, heat and cold produce therefrom fully matured products.† Aristotle's statements about the effects of heat were based on ordinary observations of everyday operations in the home and workshop. In *Meteorol.* iv. cc. 2–6, he shows that the result of the action of heat is a cooking effect, including under this phrase not only boiling and roasting, but also the ripening of fruits. He also refers to the drying effects of heat, the hardening of clay by baking, and the fusion of metals and other substances.

Aristotle expresses an opinion that heat brings together bodies of the same kind, but separates those which are not allied to each other.‡ This opinion was accepted by the

* *Meteorol.* iv. c. 1, s. 1. † *Ibid.* iv. c. 1, s. 6.
‡ *De Gener. et Corr.* ii. c. 2, 329*b*.

Aristotelians, and, in their discussions on heat, they attached great importance to it. According to Boyle, they expressed Aristotle's opinion in the short Latin formula, "*congregare homogenea et segregare heterogenea.*"* There are many exceptions to the truth of this general formula, but such exceptions were not understood by the Aristotelians. Heat does sometimes bring together substances of the same kind and separate those of different kinds, *e. g.*, when a mixture of pieces of copper and lead is melted together with a flux in a crucible, for the molten product will form three well-defined layers, the lowest containing nearly all the lead and the middle one nearly all the copper. When, however, sulphur is dropped on a bar of white-hot iron, resulting in a union of these unlike substances, and when water is vaporized by heating it, the Aristotelian formula does not hold good.

The acuteness of the sensation of heat or cold produced when the hand is placed in contact with a body depends largely upon the conductivity of the body and its heat capacity. Copper or mercury, for instance, produces a more acute sensation than wood at the same temperature. Aristotle's ideas on this subject are very imperfect, and not consistent, for he sometimes explains it by relying on differences in certain physical characters of the bodies, and sometimes by means of their assumed inherent cold or heat. In some cases, he says, the same substances produce a very cold sensation if deprived of heat, and a burning sensation when heated, the sensation being most acute in the case of bodies which are very hard or solid, *e. g.*, the sensation produced by a hot stone is more acute than that produced by hot water, and that produced by hot water is more acute than that produced by hot smoke or vapour, and similarly when these substances are cold.† In an earlier passage, he assumes that the coldness of bodies is inherent, and makes the coldness of watery and earthy substances depend on his views on the composition of these bodies from his four elements, for both water and earth are defined by the elementary *force* cold.‡ Water and substances for the most part of the nature of water, *i. e.*, liquid, were considered by Aristotle to be cold, water being particularly of a nature opposed to that of fire, but substances more of

* *The Works of the Honourable Robert Boyle*, new edition, London, 1772, vol. i. p. 488.

† *Meteorol.* iv. c. 11, s. 8.

‡ *Ibid.* iv. c. 11, s. 3.

the nature of earth or air were considered to be hotter.* Oil and also mercury were exceptional, because Aristotle assumed that these contained much air,† while he considered fat to be an essentially hot substance, because it readily assumed the form of fire.‡ There is much uncertainty, Aristotle says, about the nature of oil, for, whether it be considered to be more of the nature of water or of earth, it ought to be hardened either by the action of cold or by the action of heat. It is not, however, hardened by either of these, but merely thickened by both, the reason being that oil is full of air.§ He does not state to what kind of oil he refers, but it is probable that it was some kind of fish-oil, which is not easily frozen.

Long after Aristotle's time, philosophers held that there was some body which, by its own nature, was particularly cold, and that other bodies were cold in proportion to the extent to which such essentially cold body entered into their composition. According to Boyle, this body, well known to philosophers as the *Primum Frigidum*, was considered by some to be water, by others earth, by others air, and by some nitre, but he says "that water is the *Primum Frigidum*, the opinion of Aristotle has made it to be that of the schools, and the generality of philosophers." ‖

When classifying substances, partly by their composition and partly by their behaviour under the action of heat, into three classes which would now be called combustible with evolution of much smoke, combustible without the evolution of much smoke, and incombustible, Aristotle uses the well-known term *phlogistic*, much employed before Lavoisier's time. Aristotle gives pitch, oil, and wax as examples of phlogistic substances, coal-like (*anthrakeutic*) substances as examples of combustible bodies not yielding much smoke, and bronze as an example of incombustible substances.¶

It will be convenient to discuss next Aristotle's views on the production of heat by friction. When expressing an opinion that the heat and light of the heavenly bodies are due to friction between them and the medium in contact with them, as stated already in Chapter iii., he appeals to observations on the motions of darts and other missiles through

* *Meteorol.* iv. c. 11, s. 7. † *Ibid.* iv. c. 8, s. 11.
‡ *P. A.* ii. c. 2, 649*a*. § *Meteorol.* iv. c. 7, ss. 2 and 3.
‖ *The Works of the Honourable Robert Boyle*, new edition, London, 1772, vol. ii. pp. 585 and 591.
¶ *Meteorol.* iv. c. 9, s. 37.

the air. He says that darts had been seen to be heated to such an extent that their leaden weights were melted, and adds that the shock imparted by their rapid motion to the air causes this to become fire.* This production of heat by friction is referred to in several passages in his *Meteorology*, where he tries to explain the phenomena of falling stars, comets, and other fiery appearances, as described already in Chapter iii. He was aware that the intensity of the heat generated by a rapidly moving body was greater than that generated by a body moving slowly.

So far, he relies on the results of observation, but to a large extent his ideas on the production of heat by friction depended on his conceptions about the composition of bodies from the four so-called elements. The facility with which a substance becomes ignited by friction depends, according to Aristotle, on the quantity of the element *fire* or *air*, which was most nearly related to *fire*, in the substance itself. He says that if pieces of wood, stone, or iron are heated in consequence of their motion, it is still more likely that air, which is most nearly related to fire, should be heated.†

In *P. A.* ii. c. 2, Aristotle discusses what is meant when one substance is said to be hotter or colder than another, and incidentally explains how a rough estimate of temperature may be made. It will be seen that he did not always distinguish between temperature and quantity of heat. This part of his discussion about heat is more than usually interesting, and an epitome is therefore given in the following paragraph.

Some say that blood is hot and that bile is cold, while others say that bile is hot and blood cold. If there is this difference of opinion about heat and cold, which are capable of producing distinct impressions, what is to be thought of the impressions given by senses other than touch? The difficulty may be explained by the fact that the term "hotter" is used in several different senses, so that statements apparently contradictory may all be more or less true. In what senses then is the term "hot" employed? To answer this question, it is necessary to find out what particular effect is produced by a substance which is hotter than another, or, if several effects are produced, to find out how many such effects there are. In one sense, a body is

* *De Cœlo*, ii. c. 7, 289*a*. † *Ibid.* ii. c. 7, 289*a*.

said to be hotter than another if it gives up to a body in contact with it a greater quantity of heat, and in another sense if it causes a sharper sensation when touched by anyone. This second test is not reliable, because the intensity of the sensation varies with the individual. Again, a body which causes a fusible body to melt more quickly, or more readily ignites an inflammable substance, is said to be hotter. A larger body is said to have more heat than a smaller one of the same material, and, if a body takes longer to cool than another, it is said to be hotter, and so also if the body can be heated more quickly than the other. The term "hotter" is used in all these and probably in still more senses, but it is impossible for a body to be hotter than another in all these senses. Boiling water scalds more than flame, yet it does not melt or ignite bodies like flame does, and boiling water is hotter than a dull fire but becomes cold more quickly than the fire, for fire never becomes cold, whereas water does.

It is obvious from all this that Aristotle had no means of determining temperatures, even approximately, and that he was well aware that such rough methods as were available were quite unreliable. His discussion of the meaning of the term "hotter" shows, however, that he had attempted to make some relevant observations or experiments. If he had had even an approximately reliable means for measuring temperatures, he would at once have found that a dull fire or a flame, say of oil or wood, was much hotter than boiling water. The statement he makes about the fire keeping hot longer than boiling water shows that the generation of heat by combustion was not known to him. The phenomena of combustion were not correctly described, in fact, until long after Aristotle's time by Lavoisier. Just as Aristotle believed that some bodies were essentially cold, so he believed that others were essentially hot, and that this was the reason why some bodies cooled faster than others, although they were hotter to the touch. He decided that, in bodies which are not inherently hot but become hot by being heated externally, cold is not a mere privation of heat, but an actual existence.*

Animal heat is discussed by Aristotle in many scattered passages in his *Parts of Animals*, *Generation of Animals*, *History of Animals*, and the *Parva Naturalia*. He believed

* *P. A.* ii. c. 2, 649*a*.

that there was a relation between the quantity of animal heat, which he considered to be something different from ordinary heat, and the nature of the soul or vital principle of an animal. He says that in animals a nobler soul or vital principle must necessarily be associated with a greater amount of heat.*

He does not say much about the way in which he believed that the animal heat was generated, but, after deciding that it is not produced as a result of respiration, says that it is rather from the food that heat is produced.† He not only believed that heat was not produced as a result of respiration, but, as will be seen further on in this chapter, that respiration had a cooling effect.

Animal heat plays an important part in the digestion of food, as is well known, but Aristotle believed that it actually effected digestion.‡ Further, he believed that it had some vital influence, being different from the heat from a fire.§

He refers to the necessity for regulating the heat of an animal and guarding against the destructive effects of excessive heat.‖ Very small animals and those without blood are sufficiently cooled, he says, by the air or water in which they live, for they have but little heat.¶ Fishes and other animals with gills and blood are cooled by water flowing over the gills through which the blood passes from the heart.** In mammals, birds, reptiles, and amphibians, the regulation of heat is effected mainly by means of the lungs,†† the air flowing through ramifications of the bronchial tubes, which run so closely alongside the branches of the blood vessels in the lungs that the blood is cooled and some air actually finds its way into the blood, which is also cooled thereby.‡‡

According to Aristotle, the lungs were not the only heat-regulating means, in animals with blood. The brain, which he did not regard as the sensory centre, was believed by him to have as its most important function the regulation of the heat of the body, and especially the heat of the head, where the chief sensory organs are situated.§§

Several interesting instances of the application of heat in the arts are described by Aristotle in various parts of his

* *De Respir.* c. 13, 477*a*.
‡ *P. A.* ii. c. 3, 650*a*.
‖ *De Respir.* c. 8, 474*b*.
** *Ibid.* c. 21, 480*b*.
‡‡ *H. A.* i. c. 14, s. 3.
† *Ibid.* c. 6, 473*a*.
§ *G. A.* ii. c. 3, 736*b* and 737*a*.
¶ *Ibid.* c. 9, 474*b*.
†† *Ibid.* c. 15, 478*a*.
§§ *P. A.* ii. c. 7, 653*a* and *b*.

works, and a discussion of some of these will close this account of Aristotle's description of the phenomena of heat.

It seems to have been usual for people living near the Black Sea to encamp on the ice, for the purpose of fishing, and to secure their tent poles in holes made in the ice. In order to make the poles very secure, Aristotle says that they poured hot water round the lower parts of the poles, and that the ice formed by the rapid freezing of the water was a substitute for lead.* He also says that it was a common custom for some people, when they wished to freeze water quickly, to expose it first to the heat of the sun.†

Aristotle describes the manufacture of pearl-ash by the Umbrians, who burnt plants, boiled the resulting ash in water, and finally cooled down to crystallize the salts produced.‡

In *Meteorol.* iv. c. 6, s. 7, Aristotle refers to the distortion of articles of potters' clay, if these articles, hardened by cold or frozen, are placed in the oven. He explains the distortion by saying that there is a temporary softening of the clay by the action of the water resulting from the thawing during the first stage of the baking process.

Aristotle gives a short account of the production of steel. "Worked iron," he says, can be heated so as to be liquescent, and then can be solidified again, and, in this way, they make steel, for the slag falls down beneath and is cleared off. When this process has been carried out many times, and the metal has become pure, steel is produced.§

The "worked iron," which might at first sight be taken to be wrought iron, can scarcely be this metal, because Aristotle's description shows that the "worked iron" was comparatively easily fusible, whereas wrought iron is not so. He says, in fact, in an earlier passage,‖ that iron can be melted only by a very intense heat, but it can be softened. Here he evidently refers to wrought iron, or, perhaps more correctly, a steely iron. The "worked iron" was probably a crude steely iron, containing manganese, such as could be obtained from the manganiferous iron ores of Greece, by the ancient process of extraction by means of carbon. Unfortunately, Aristotle does not describe the method of extraction. The method of making steel, described by him, consisted in repeatedly heating the crude steely iron, each heating resulting in an elimination of some of the im-

* *Meteorol.* i. c. 12, s. 18.
† *Ibid.*
‡ *Ibid.* ii. c. 3, ss. 42 and 43.
§ *Ibid.* iv. c. 6, s. 9.
‖ *Ibid.* iv. c. 6, s. 8.

purities. The way in which he refers to the separation of the slag shows that, as might be expected, the slag was a very fusible silicate of iron and manganese, each removal of slag resulting in a corresponding loss of iron. He himself says that steel was not often made because of the great loss of iron, but less refining was needed when the iron used was of good quality.*

Aristotle's statements about sound are comparatively few in number, and occur chiefly in his *De Anima*. There is but little information on this subject in his *De Sensu, &c.*, where such information might be expected to be found. In a small Aristotelian treatise, the *De Audibilibus*, are also a few interesting statements on sound, but it is generally admitted that this treatise was not written by Aristotle.

His observations on sound furnish little that was original. He reproduces in clearer language some facts which were well known before his time, *e.g.*, that sound was a motion of the air or other sounding body, that such motion was transmitted in some way to the ear and caused a sensation of hearing, and that an echo was due to a rebounding of the air, a bending back or reflection of the voice. In the production of an echo, he believed that the air rebounded like a ball off a mass of air which, on account of its being prevented from dispersing by reason of its filling a cavity or vessel (ἀγγεῖον), acted like a solid or resisting body.†

When a body, such as a bell, is sounded, there are, as is well known, four things which contribute to the result: the hammer of the bell, the bell itself, the air acting as a medium of transmission, and the ear. Aristotle, however, held that an important condition was that the air should withstand the blows causing its motion and should not yield laterally or disperse. If the air were struck forcibly and suddenly, it would be unable to yield, but if the blow were weak and slow in its action, the air would have time to escape or disperse, and no sound would be produced. It was partly for these reasons that he seems to have believed that wool and other light substances, enclosing many air spaces, were not sounding bodies, while bronze articles and other hard bodies, which were polished and had no crevices or recesses into which air could escape, were sounding bodies.‡

* *Meteorol.* iv. c. 6, s. 10. † *De Anima*, ii. c. 8, 419*b*.
‡ *Ibid.* ii. c. 8, 419*b*.

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Aristotle appears to have believed that the motion to which sound is due travels in a straight line, and not in all directions, if the medium is unbroken. There is not any passage in his works which seems to represent clearly his views on this subject, but in the Aristotelian treatise, *De Audibilibus*, it is stated that it is shown, by means of ships' masts and long pieces of wood, that sound travels in a straight line, for if these are struck at one end the sound is carried straight along, unless there is a chink in the wood, and it bends back at the knots and cannot proceed in a straight course.*

Aristotle says that sound is heard in water, but to a less extent than in air.† Sound is heard more distinctly in water than in air, as is well known, and it is very probable that Aristotle was relying not on experiment but merely on abstract reasoning.

It is stated in the *Problems*, xi. 23, that in the production of an echo the reflection is in the direction of a like angle, and therefore the voice of the echo is like the voice to which it is due. The *Problems* is an Aristotelian treatise, probably not written by Aristotle, but the above statement shows that the writer knew that, in the case of sound, the angles of incidence and reflection are equal.

* *De Audibilibus*, 802. † *De Anima*, ii. c. 8, 419*b*.

CHAPTER V.

DISTINCTION BETWEEN ANIMALS, PLANTS, AND INANIMATE MATTER.

The determination of a distinguishing feature between animals and plants, and of the relationship between forms of life and inanimate matter, has long engaged the attention of naturalists and others. Many passages in Aristotle's works show that he also considered this very difficult question.

He probably had no knowledge of the lowest forms of life, and his knowledge of some forms, such as, for instance, jelly-fishes, sea-anemones, and sponges, was comparatively slight. He observed, however, that some animals resembled plants in certain respects, and that some forms of life originated under circumstances such as to suggest that they were generated from inanimate matter. Having made observations of this kind, he made the following important statements, which seem to show that he believed in spontaneous generation (*αὐτόματος γένεσις*), or, as it is sometimes called, abiogenesis, and in a continuous gradation from inanimate matter to the highest forms of life. He says: "Thus Nature passes by degrees from inanimate things (*ἄψυχα*) to living beings, so that owing to their continuity the boundary between them escapes notice, and there is an intermediate common ground. For, first after the class of inanimate things comes the class of plants, and each of these differs from the rest in seeming to partake of life to a greater or less extent, and the whole class seems to be alive compared with other bodies, but lifeless compared with animals. The passage from them to animals is continuous, as I said before, for anyone would be quite at a loss in deciding whether some marine forms of life are plants or animals, for they are attached to the sea-bed, and many of such forms of life die when they are removed from it."* Again, he says: "For Nature passes in an unbroken man-

* *H. A.* viii. c. 1, ss. 2 and 3.

ner from inanimate things to animals, through forms of life which are not animals, in such a way that one class seems to differ very little from another in the part where they border on each other." *

These ideas were not altogether original, but had been partly foreshadowed by other philosophers. Empedocles, Democritus, and others considered that plants had sensation and cognition, as will be seen later in Chapter vii. They believed, in fact, that the vital principle of plants was nearly the same as that of animals.

In the above passages from Aristotle's *H. A.* and *P. A.* the word ἄψυχον is employed several times. It signifies something without ψυχή, which may be translated "vital principle," although it is doubtful whether there is any English word or phrase which exactly corresponds with the meaning intended by Aristotle. This vital principle is described chiefly in his *De Anima.* It is that active principle which, in association with bodies, organized in some way, gives rise to the phenomena of life. The word "organized" is used here only for the sake of convenience; taken without qualification, it represents a knowledge of the constitution of matter far more advanced than Aristotle's ideas on that subject. He considered the vital principle to be related to living bodies in a manner comparable with the relationship of Form to Matter, or Sight to the Eye, and says that if an eye were a living being, then sight would be its vital principle.† He contemplated several kinds of vital principle, manifested by functions of different degrees of dignity or importance, the chief being: (1) the Nutritive; (2) the Sentient, and (3) the Intellectual. Whatever has one of these principles is said to live, and Aristotle assigned only one to a form of life, because the sentient includes the nutritive, and the intellectual includes both the nutritive and the sentient vital principles. All forms of life have the nutritive vital principle at least.

In his contemplations of forms of life, Aristotle considered the vital principle to be more important than the matter associated with it, yet the constitution of this matter had to satisfy some conditions to enable the vital principle to be associated therewith. He does not seem to suggest that the vital principle could be associated with a sculptured block of marble or an image cast from bronze. He believed,

* *P. A.* iv. c. 5, 681*a*. † *De Anima*, ii. c. 1, 412*b*.

however, that forms of life were generated spontaneously from earth, mud, sand, foam, or the dew which falls on plants.

In order that lifeless matter may become living matter, some vital principle must be associated with it, but it is difficult to understand in what way Aristotle believed that this association was effected. It could not be, apparently, by a transfer of vital principle alone to non-living matter, for Aristotle persistently asserts that the vital principle, that, at least, to which nutritive or sentient faculties are due, cannot have a separate existence. He gives some explanation of his views in several passages, especially in his *G. A.* iii. c. 11. According to these, the inanimate matter undergoes some kind of maturing process in presence of moisture and at a suitable high temperature, the moisture containing some breath of life (πνεῦμα), and everything being in some way full of vital principle (ψυχή). Then frothy bubbles of this specially prepared matter are formed, and within these generation proceeds rapidly. The nature of the forms of life thus formed will depend partly on the nature of the matter caught up within the bubbles and partly on the nature of the vital principle enclosed.

This is a short summary of the way in which Aristotle believed that spontaneous generation was effected. Another important statement, giving some indication of his views on the subject under discussion is the following :—"The part of the rudimentary vital principle (ψυχικὴ ἀρχή) caught up and enclosed in the breath of life (πνεῦμα) makes the germ or embryo and imparts movement."*

It is not clear what this πνεῦμα was intended to be. In some translations of this and other passages on spontaneous generation, πνεῦμα is rendered by "air", but this is incorrect, for, apart from differences in meaning between πνεῦμα and ἀήρ, the usual Greek word for air, Aristotle says that air (ἀήρ) is not present and cannot remain in water.† The same assertion is also made in the Aristotelian treatise, *De Spiritu*, c. 2, 482.

Many parts of the passages in Aristotle's works on spontaneous generation are general statements covering many important details in the steps of the process. It is not surprising that he makes no attempt to trace these details.

* *G. A.* iii. c. 11, 762*b*.
† *De Sensu, &c.*, c. 5, 443*a*; *De Respir.* c. 2, 471*a*.

The chief forms of life which were believed by Aristotle to be generated spontaneously were:—(1) some flowerless plants; (2) many of his *Ostrakoderma*, especially those now called gastropods and lamellibranchs; (3) some of his *Entoma*, and (4) some fishes, such as, for example, eels and certain kinds of mullets. These forms of life, different as they are both in structure and in the amount of vital principle they seem to possess, resemble one another, according to Aristotle, in being generated immediately from inanimate matter. To this extent, therefore, the two important passages from *H. A.* viii. c. 1, and *P. A.* iv. c. 5, previously cited, are clear. Some of these forms of life resemble one another sufficiently to form an assemblage which unites inanimate matter with higher plants and animals, such as flowering plants, insects, crustaceans, cephalopods, and the numerous animals constituting Aristotle's *Enaima*, which corresponds to a large extent with the Vertebrata.

The ancient Greeks had no difficulty in believing in spontaneous generation, and even Aristotle took the trouble to consider the common saying that men and some quadrupeds were generated from the earth. It is true that he was not inclined to believe in generation from the earth itself, but he seems to have admitted the possibility of generation of men and some quadrupeds from much lower forms of life, for he says that, if generation from the earth did happen, it must have been generation from worms or larvæ, or from ova.*

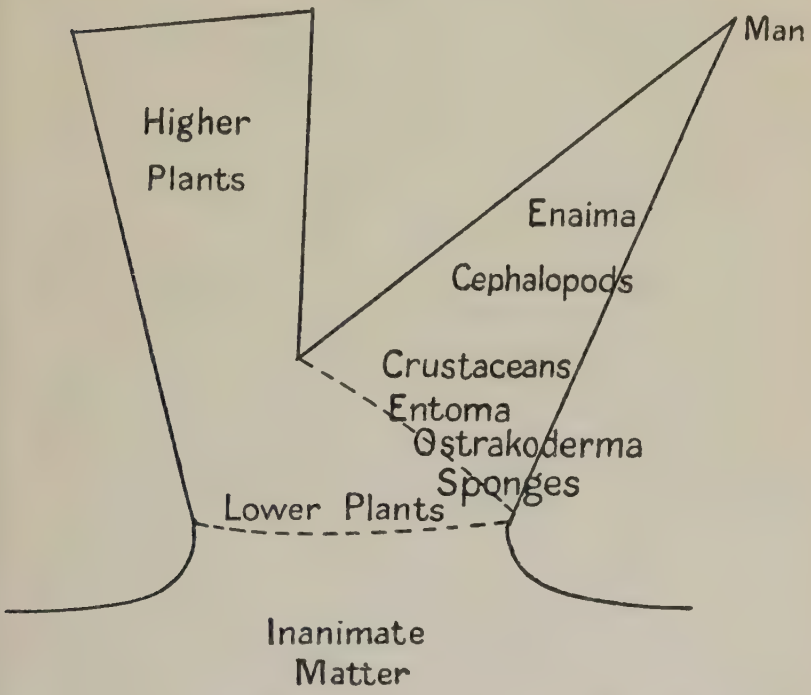
In *H. A.* ii. c. 5, s. 1, he says that the Barbary Ape and other monkeys and also baboons partake of the nature of both men and quadrupeds. Neither in this nor, apparently, in any other passage does Aristotle show that he had any idea of a development of higher forms of life from common ancestors, at all resembling the Darwinian idea of the origin of species. When referring to Aristotle's statement about the Barbary Ape, Agassiz says that Strack in his translation† makes Aristotle say that monkeys form a transition between men and quadrupeds, but the original says no such thing.‡ This is quite true, and the comment by Agassiz illustrates the danger of translating Aristotle too freely.

Aristotle had some knowledge of no fewer than five

* *G. A.* iii. c. 11, 762*b*.
† *Aristoteles Natur. der Thiere*, 1816, p. 65.
‡ *An Essay on Classific.*, London, 1859, p. 97, Note.

hundred and twenty forms of life, and between some of these he noticed that there were resemblances, while they differed in the nature and quantity of vital principle which they seemed to possess. Some forms of life contained very little or none of the sentient vital principle. It was through these that Nature passed from inanimate material to undoubted plants and animals. This is exemplified in Fig. 4, which sufficiently explains itself.

FIG. 4.



In Aristotle's ascending scale, plants succeed inanimate bodies. They have the lowest form of vital principle, the nutritive,* and exhibit movements due to growth and decay.† They do not move from place to place, and, although they are affected in some way by objects which touch them, they have no sensory faculty.‡ Compared with one another, they differ in the amount of vital principle which they possess.§

* *De Anima*, ii. c. 2, 413*b*, ii. c. 3, 415*a*.
† *Ibid.* iii. c. 9, 432*b*.
‡ *Ibid.* ii. c. 12, 424*a*.
§ *H. A.* viii. c. 1, s. 2.

Animals have some part at least of the sentient vital principle, and are distinguished by being capable of sensation.* Some have all the senses, and others have certain senses only, but all have the sense of touch,† so that their life is defined by this.‡

It will thus be seen that an object which clearly contracted on being touched, or which moved bodily from place to place, would be classed by Aristotle with animals. There were also what may be called his border-line forms of life, such as, for instance, his *Holothouria*, which showed some features indicating that they were plants and also others indicating that they were animals. Let us consider a few of these forms of life and the way Aristotle proposed to classify them.

The fixed ascidians, Aristotle's *Tethya*, resembled plants in always being attached to some object, but, since they had a kind of fleshy substance, it must be assumed that they had some degree of sensibility; further, these animals did not seem to have any distinct waste matters from their nutriment, and, in this respect, they resembled plants.§ He considered them to be animals which had a sense of smell developed only to a very slight extent.‖

The forms of life to which he gave the name *Akalephai* included some of the Medusæ, Actiniæ, and other Cœlenterata. He considered that they were animals, because some of them became free and could capture their prey, but that, like plants, they had no distinct waste matters.¶

A satisfactory identification of Aristotle's *Holothouria* does not seem to be possible. He says that they are free forms of life incapable of moving from place to place,** and that they are devoid of sensation and live like certain plants which exist free from the soil.†† This is all the information he gives about them, and it is not quite clear whether he intended to class them with plants or animals. Some have attempted to identify them with sea-cucumbers (*Holothuriæ*), but such identification is unsatisfactory, for sea-cucumbers show marked signs of feeling. Prof. E. Forbes, after describing the common holothurians of the eastern Mediterranean, and expressing an opinion that they are not the

* *P. A.* ii. c. 8, 653*b*; *G. A.* ii. c. 5, 741*a*.
† *H. A.* i. c. 8; *De Anima*, ii. c. 2, 413*b* and 414*a*.
‡ *Ibid.* iii. c. 13, 435*b*. § *P. A.* iv. c. 5, 681*a*; *H. A.* viii. c. 1, s. 3.
‖ *H. A.* iv. c. 8, s. 19. ¶ *P. A.* iv. c. 5, 681*b*; *H. A.* iv. c. 6, ss. 4–5.
** *H. A.* i. c. 1, s. 8. †† *P. A.* iv. c. 5, 681*a*.

same as the *Holothouria* of the Ancients, suggests that Aristotle may have had in view "the large, round, sponge-like algue called *Spongodium*, living free on the sea-bed and abundant in the Greek seas." *

Aristotle's statements about sponges are remarkable, and, until the eighteenth century, naturalists do not seem to have added much further information about them. Besides giving a great deal of other information about sponges, he says that they are animals resembling plants very closely, because they cannot live when torn away from their places of attachment,† and that they show signs of feeling, a proof of this being that, according to common report, they contract when an attempt is made to tear them away, or when the winds and waves are violent; the people of Torona, he adds, deny that this is so.‡

His conclusion, that sponges are animals, apparently based on very slender data, is interesting, because naturalists were long undecided on this question. Gesner, Rondelet, and Belon were disposed to consider them to be plants, Ray and Tournefort classed them with plants, and Linnæus, Lamarck, Milne-Edwards, Cuvier, and many others considered them to be animals. It may be mentioned that the opinion of Linnæus changed, *e.g.*, in the tenth edition of the *Systema Naturæ* sponges are classed with plants, and in the twelth and thirteenth editions, with animals.

The assumed contractility of sponges, based on hearsay evidence, but denied by the people of Torona, in Macedonia, seems to have formed the chief reason why Aristotle considered sponges to be animals. However, sponges do not seem to exhibit any such contractility, for Dr. Grant, after numerous experiments on sponges, found no trace of it, and he also says that several other investigators had been unable to detect it in sponges found in many different localities.§

There is another matter deserving of consideration in connection with Aristotle's decision that sponges are animals, *viz.*, the extent to which he relied on popular beliefs. The many passages on sponges, in his works, show that he studied these animals in some detail, but it is worthy of note that, when speaking of their showing signs of feeling,

* *Travels in Lycia, &c.*, 1847, vol. ii. p. 118.
† *H. A.* viii. c. 1, s. 3; *P. A.* iv. c. 5, 681*a*.
‡ *H. A.* i. c. 1, s. 8, v. c. 14, s. 3.
§ *Edin. Philosoph. Journ.*, vol. xiii. 1825, pp. 342–6, vol. xiv. 1826, pp. 120–4.

he seems to rely on what was told him by others, probably fishermen. I have not been able to find a passage in the ancient writers showing that fishermen of Aristotle's time believed that sponges were animals. At a much later time Gesner was influenced by a popular belief of this kind, for he says: "I do not think that the Sponge is an animal; indeed, it is scarcely a zoophyte; since, however, some of the common people think that it is some kind of animal and, on this account, Rondelet and Belon have treated of it in their histories of aquatic animals, I also shall deem it worthy to be included in my supplement.*

It is not easy to ascertain what is the general popular opinion on the nature of sponges in the Greek area. Dr. W. H. D. Rouse informs me that the sponge is spoken of in terms which would suit an animal, and Mr. G. C. Zervos, writing from Calymnos, on October 23rd, 1907, says: "The Sponge is considered to be an animal, because the Sponge fishermen say that ἐψόφησαν τὰ σφουγγάρια = (the Sponges have become dead), and the word ψοφῶ is used in modern Greek to denote the death of animals only." Wishing to obtain information as definite as possible, I wrote to Mr. W. R. Halliday at the British School at Athens. He replied (after his return from a journey which included Melos and Paros) in a letter received June 24th, 1911, as follows: "I think I can answer your question about sponges in the negative. I have put it in the following forms on different occasions: 'Are sponges animals or plants?' to which the answer is 'Plants.' 'Are sponges animals?' 'No, plants.' 'Are sponges plants?' 'Yes, of the sea.' In no case have I found any hesitation, or leaning towards the animal theory."

Evidently, the popular opinion among some Greeks is that sponges are plants, and it is possible that Aristotle was not merely recording a popular belief when he said that sponges are animals.

The distinctions between animals and plants which Aristotle attempted to make have long become insufficient; in fact, they were scarcely sufficient for the comparatively very few lower forms of life known to him. The well-known definitions of stones and like substances, plants, and animals, made by Linnæus, were like those of Aristotle, except that stress was laid on the fact that animals and plants are organised, while stones and the like are unor-

† *Hist. Anim.* iv. Corollarium, 1558, p. 1066.

ganized. Later naturalists found that these definitions were unsatisfactory. Then importance was attached to the absorption of nutriment by fibres at the lower ends of plants and the presence in animals of a mouth above or anteriorly, leading to a stomach. Next, naturalists sought a reliable distinction between plants and animals in the exhalation of carbonic acid by animals and oxygen by plants. With increasing knowledge of new forms of life, all these distinctions were found to be unsatisfactory, and new ones were suggested, depending on, *e.g.*, the nature of the cell, the properties of protoplasm, the presence or absence of chlorophyll, and the nature of the food of animals and plants. To-day, however, the difficulties are confined chiefly to the numerous very small forms of life of which Aristotle and even Linnæus and many later naturalists had no knowledge. With respect to such small forms of life, Sir Ray Lankester says: "When, however, we come to the very lowest unicellular microscopic forms of life, there is greater difficulty in assigning some of the minuter organisms to one side or the other, and to some extent our decision in the matter must depend on the theory we may provisionally adopt as to the nature of the earliest living material, which was the common ancestral matrix from which both the Plant series and the Animal series have developed." *

It is clear, therefore, that Aristotle, when he attempted to determine a boundary line between animals and plants, became the pioneer of a work which has engaged the attention of numerous investigators right up to the present time. He was not aware of the complicated nature of the phenomena which it would be necessary to understand before so difficult a task could be completed, but he made a creditable attempt. That he knew only comparatively few forms of life, and that he had great difficulty in deciding on the nature of some, the position of which has long been determined, do not deprive him of the credit of being the first to indicate how a boundary line may be drawn between plants and animals.

* *A Treatise on Zoology*, part i. 1909, p. xiv.

CHAPTER VI.

CONSTITUENTS OF ANIMALS, PLANTS, AND INANIMATE MATTER.

Aristotle's conceptions about the constituents of animals, plants, and inanimate matter were connected with his views about motion. It has been stated already that he believed that there was but one Kosmos or Universe, that this was of spherical form, and that the Earth was at its centre. He held that all motions of bodies could be resolved into three simple motions: (1) rectilinear motion upwards or outwards from the centre; (2) rectilinear motion downwards or inwards towards the centre, and (3) circular motion. A simple body or element must have, according to Aristotle, a simple motion, and, from a consideration of the motions which earthy substances, water, air, and flame exhibit, he concluded that there were four elements, *earth*, *water*, *air*, and *fire*, of which *earth* and *water* correspond to rectilinear motion towards the centre, and *air* and *fire* correspond to rectilinear motion from the centre. To circular motion he assigned a fifth element, *æther*, distinguished by being eternal and indestructible, undergoing no change either in quality or quantity. This element, since it could not move in a rectilinear direction, either upwards or downwards, had neither lightness nor heaviness. He believed that this element existed in the upper regions of the Kosmos or, at any rate, at some distance from us. He does not appear to have considered it to be a part of terrestrial bodies.* On the other hand, *earth*, *water*, *air*, and *fire*, which enter into the composition of terrestrial bodies, are not eternal, and require to be renewed by generation.†

Aristotle was not the first to consider that *earth*, *water*, *air*, and *fire* were the elements from which all terrestrial substances are made. Empedocles, in somewhat figurative language, was the first to do this, as Aristotle himself clearly

* *De Cœlo*, i. cc. 2 and 3, iii. cc. 3 and 5. † *Ibid.* ii. c. 3.

shows.* Aristotle, however, preferred to carry his analysis still further. He considered these so-called *elements* to be compounded of the *forces* (δυνάμεις) to which he gave the names Hot, Cold, Wet, and Dry.† The Hot and Cold were considered to be active, and the Wet and Dry passive.‡ The way in which these *forces* were combined to form the *elements* is usually represented graphically in the

FIG. 5.

way shown in Fig. 5. The combinations shown are the only ones, because heat and cold, wetness and dryness, are contraries which cannot exist together. This conception of the composition of bodies out of the *forces*, rather than out of the so-called *elements*, agrees better with Aristotle's statement, in *De Cœlo*, ii. c. 3, that the *elements* act on each other and, as a result, destroy each other.

* *Metaphys.* i. c. 4, 985*a*; *De Gener. et Corr.*, ii. c. 1, 329*a*.
† *P. A.* ii. c. 1, 646*a*; *De Gener. et Corr.*, ii. cc. 2–5.
‡ *Meteorol.* iv. c. 1, s. 1.

The manner in which Aristotle considered bodies to be made up from the *elements* may now be considered. He says that there are three degrees of composition, the first being that out of the so-called *elements*, such as *air*, *earth*, *water*, and *fire*, or, he says, it would be better to say out of the *forces* referred to above, the second degree of composition being that by which the homœomeria,* such as blood, flesh, bone, stone, and the like, are formed out of the *elements*, and the third being that by which the anhomœomeria,† such as the face, hand, and many other parts, are formed out of the homœomeria.‡ With respect to the first degree of composition, Aristotle considered that all forms of matter, animate or inanimate, contained some quantity of each of the *elements*, combined together and not merely in a state of mixture, and that the differences in the properties of these forms of matter, such as differences in heaviness or lightness, roughness or smoothness, were consequential on the proportions of the *elements* present.§ Consequently, each of the substances earth, water, air, and flame, as they are known to us, contain some quantity of each of Aristotle's *elements*, but earth, water, air, and flame contain preponderating proportions of the elements *earth*, *water*, *air*, and *fire*, respectively. Other forms of matter, even such different substances as stone and palm oil, contain the same elements; their differences are due merely to the different proportions in which these elements are present. The stone contains a preponderant quantity of *earth*, and the oil contains comparatively large amounts of *air* and *water*. The oil, if liquid, may be made solid, as is well known, without any change in its chemical composition, but, according to Aristotle's views, the solid oil would differ from the liquid oil chiefly by containing smaller amounts of *air* and *water*.

Clearly, therefore, Aristotle believed that a change in the relative proportions of the *elements* in a substance resulted in the production of a substance having properties different from those of the original substance. This was not all; it will be evident, from the following account of his views on the constitution of substances, that he held that the *elements* existed in a state of combination and not mere

* The homœomeria will be discussed chiefly in Chapter ix.

† The anhomœomeria will be discussed chiefly in Chapters x.–xii.

‡ *P. A.* ii. c. 1, 646*a*.

§ *Ibid.* ii. c. 1, 646*a*; *De Gener. et Corr.* i. c. 10, 328*a*, ii. c. 8, 334*b* and 335*a*.

mixture. He uses three words in a technical sense, σύνθεσις, μῖξις, and κρᾶσις. According to Aristotle's explanation of these words, they respectively mean a mechanical mixture, a compounding of solid bodies so as to produce a body absolutely uniform in composition (the solid bodies having been so blended that not even the smallest particle of any of them can be detected), and a compounding of fluids in the same way. He says that, since bodies cannot be divided into indivisible particles, and *synthesis* and *mixis* are different, we ought not to say that in *mixis* the small particles of the mixed bodies preserve their individuality, for the result of the *mixis* is a homœomerion. Nothing of this kind would result, he says, from a mixture of indivisible particles, for, if it were possible to examine the mixture with the eye of Lynceus, it would be seen that the mixture was not a *mixis*, although it might seem to be so to one with ordinary sight.*

Aristotle, therefore, had some ideas of what is now called chemical combination, but he held that his *elements* combined in every conceivable proportion; his compounds were more like some alloys than chemical compounds. Believing that all bodies were formed from four *elements*, and that these *elements* were capable of combining in all proportions, it is not surprising that the alchemists, who were greatly influenced by Aristotle, persisted so long in their efforts to transmute the baser metals into gold.† That Aristotle's ideas were very crude may be seen from the following examples, the first of which is taken from his own writings. In the production of bronze there is usually a rather large loss of tin by oxidation and vaporization, but the rest of the tin alloys with the copper with the production of a bronze which is much harder and of a lighter colour than the copper. According to Aristotle, the tin nearly vanishes during the production of the alloy, its effect being merely to modify the colour of the alloy, because the copper

* *De Gener. et Corr.* i. c. 10, 328*a*.

† Researches on the transmutation of certain elements into other elements have been made during recent years by Sir William Ramsay and others (see *Journal of the Chemical Society*, 1907, pp. 1593–1606; 1909, pp. 624–637). Sir William Ramsay says: "The undoubted fact that the well-known helium is a product of the 'degradation' of radium must be held to be thoroughly established. And in this instance, one certain case of transmutation is sufficient" (*Journ. of the Chem. Soc.*, 1909, p. 626).

It may be of interest to state that there is a Specification for British Letters Patent, No. 26356, A.D. 1910 (Roux), for transmuting iron into silver and gold.

acts more strongly on the tin, which cannot act strongly on the copper.* Again, if water be deprived of its hydrogen, a gas is left having properties very different from those of water. On Aristotle's assumption, this should be explained by saying that the water had been changed by an addition of the element *air*, whereas hydrogen, which would be of the nature of Aristotle's element *air*, has been taken away. He was also quite unaware that the physical properties of a substance may be changed while its composition remains the same.

Respecting the physical constitution of matter, Aristotle held that matter was continuous and not made up of indivisible parts.† He rejected the atomic theories of Leucippus, Democritus, and other ancient Greek philosophers who considered matter to consist of *atoms* or small indivisible particles separated by interspaces and in a state of motion. This theory has only a superficial resemblance to the modern atomic theory of chemists, and was open to the objection that it did not satisfactorily explain how the *atoms* were held together. Aristotle's theory that matter was continuous was at least not open to this objection. Compared with the theories of the ancient atomists, it might be said that, broadly speaking, matter was considered by Aristotle to be vitreous or colloidal, and by the atomists to be granular. The modern theory takes account of the action of chemical and physical forces which were quite unknown both to the atomists and to Aristotle.

The substances, or homœomeria, resulting from the combination or *mixis* of the elements *earth*, *water*, *air*, and *fire*, will next be considered. According to Aristotle, a part of a homœomerion, such as flesh, may be correctly called by the name given to the homœomerion itself, but a part of an anhomœomerion, such as a hand, cannot be properly designated by the name of the anhomœomerion.‡ He gives numerous examples of his homœomeria, such as, for example, flesh, blood, splanchnon or vascular material forming the liver and other chief viscera, fat, marrow, milk, bile, tendon, cartilage, bone, wood, stone, bronze, gold, silver, and other metals. These examples show that Aristotle's

* *De Gener. et Corr.* i. c. 10, 328*b*.

† *Physics*, iii. cc. 6 and 7.

‡ *H. A.* i. c. 1, s. 1; *P. A.* ii. c. 2, 647*b*, ii. c. 9, 655*b*; *De Gener. et Corr.* i. c. 1, 314*a*.

homœomeria are materials, some of which may be constituent tissues.

It is evident from Aristotle's definition of homœomerion and anhomœomerion that his views were dependent to some extent on the way some words were used by the ancient Greeks. This causes some difficulty in a few cases. He explains that some constituent parts of animals may be considered to be homœomeria, if their material only is considered, or anhomœomeria, if the functions are taken into account, and that the only reason for classifying skin, membrane, nail, horn, &c., with the homœomeria is that the name of any one of them happens to be used to denote a part of it also.*

Considerations based on the homogeneity of the parts do not appear to be important in Aristotle's views on the homœomeria; for instance, he says that they may vary in themselves, and that blood, which is one of the best defined of his homœomeria, may be of varying degrees of consistency, turbidity, and temperature, even in the same animal.†

The terms "homœomeria" and "anhomœomeria" appear to be Aristotle's own, but the distinction involved in their use had been expressed by Plato, in *Protag.* xviii., where he prefers to consider justice, temperance, and holiness to be parts of virtue in the same sense as the mouth, nose, and eyes are parts of the face, rather than that they are like parts of a block of gold, which differ from the whole and from one another only in size.

Aristotle's third degree of composition may now be considered. The homœomeria are combined to form the anhomœomeria, of which he gives many examples, such as, for instance, the face, eye, tongue, arm, foot, wing, and the heart and other chief viscera. These show that his anhomœomeria are parts having definite forms or functions. This is in accordance with his own statements. He tells us that the heart, like the other chief viscera formed of vascular material, is of the nature of a homœomerion, but is also an anhomœomerion, because it has a definite form.‡ Again, his anhomœomeria may be characterized by possessing a capability of performing work, of doing something.§ Generally speaking, his organic anhomœomeria are members or organs of the body, and he considered the bodies of some

* *P. A.* ii. c. 9, 655*b*. † *Ibid.* ii. c. 2, 647*b*.
‡ *Ibid.* ii. c. 1, 647*a*.
§ *H. A.* i. c. 3, ss. 2 and 3; *P. A.* ii. c. 1; *G. A.* i. c. 18, 722*b*.

animals, *e.g.*, men, birds, and fishes, to be made up of anhomœomeria. His examples of anhomœomeria are almost entirely taken from the animal kingdom, but it is clear that a branch of a tree or a leaf, a wooden ball, a table, or a sword would be anhomœomeria.

The distinction made by Aristotle between anhomœomeria and homœomeria corresponds, in an elementary way, with the modern distinction between the organs of the body and the tissues of which they consist, a distinction mainly due to the labours of Bichat, who lived as late as the end of the eighteenth century. Aristotle's homœomeria, however, include not only constituent parts of the organs, but also matters which can be regarded as secretions and ejecta only.

Aristotle knew but very little indeed of the structure or composition of the homœomeria. Modern anatomists break up organic homœomeria, such as fat, skin, and flesh, into cells, muscle fibres, and connective and other tissues, but he does not appear to have known anything of these. It may be suggested that the vesicles, which he believed were formed in the process of spontaneous generation, were some kind of animal or vegetable cells, but there is nothing to support such a suggestion in the rest of his works. The following, in fact, seems to represent all he knew about the structure or composition of his homœomeria. He knew of the presence of fat in the substance of the liver, in flesh, and in milk, he knew also that certain fibrous structures occur in flesh, and he was aware that "fibres," corresponding with what is now called *fibrin*, could be extracted from blood, after it had been drawn from the body of an animal.

In Chapter ix. a detailed account will be given of Aristotle's homœomeria.

CHAPTER VII.

ON PLANTS.

THERE are many passages in Aristotle's works which show that he contemplated writing a separate treatise on plants, and it is probable that he wrote a treatise of this kind. No work on plants, however, which can be assigned with confidence to Aristotle has been found. There is a small Aristotelian treatise entitled *De Plantis*, considered by some to be one of Aristotle's genuine works, but usually admitted to be spurious. The only genuine sources from which his views on plants can be obtained are, in fact, a large number of passages which occur, almost incidentally, in some of his works, particularly his *History of Animals*, *Parts of Animals*, *Generation of Animals*, *De Anima*, and the *Parva Naturalia*. It will be best to consider these passages, before discussing further the Aristotelian treatise on plants.

The passages in which Aristotle distinguishes plants from animals on the one side, and inanimate matter on the other, have been referred to already in Chapter v. There it will be seen that, according to him, plants have only the lowest form of vital principle—the nutritive, that they do not move from place to place, but exhibit movements due to growth and decay, and that they have no sensory faculty, although they are affected in some way by certain external influences.

These views, compared with those of Anaxagoras, Empedocles, Democritus, and Plato, on the nature of the vital principle of plants, are less fanciful, and indicate a much more practical and reasonable conception of plant life. It is clear from the *Timæus* and from fragments from Anaxagoras Empedocles, and Democritus, such as, for example, some which are given in the Aristotelian treatise, *De Plantis*, i. cc. 1 and 2, that they believed that plants had sensation and cognition, that, in fact, they were capable of feelings of joy and sadness.

The consideration of the nature of the vital principle, or

soul, of plants occupied the minds of many who wrote about them, and attempts were made to determine in what part or parts of the plant the *soul* resided. The general opinion was that the *soul* of a plant resided in the "heart" or pith, and, as late as the sixteenth century, Cæsalpinus seriously considered this subject. After deciding that a very suitable position for the *soul* of a plant is in the middle of the part where the stem starts from the root, he argued that a *soul* existed even in the axil of each leaf, and finally concluded that the *soul* of a plant was *veluti in omnes partes distributum*, or distributed as it were to all parts of the plant.*

The statement that plants are affected in some way by external influences† is not clear, but the context suggests that the effects of cold and heat on the plants were in Aristotle's mind.

Respecting the nutrition of plants, he says that they obtain food by means of their roots,‡ which he compares with the mouth of an animal,§ and with the blood-vessels of the umbilical cord.‖ Their food, he says, must be liquid and, although they seem to be nourished by one substance only, *viz.*, water, yet they are nourished by more than one substance, for earth is in combination with the water.¶ Plants, he says, obtain their food from the earth in a digested state, wherefore waste matters are not produced in plants, which use the earth and its heat in place of a stomach.**

Aristotle did not know anything about the nutritive importance of the leaves and other green parts, but his statement about the complex nature of the food of plants is correct as far as it goes. The most remarkable parts of his statements about the nutrition of plants are, however, those relating to the function of the soil and the consequent absence of waste matters in plants. He is reasoning, as he often does, by analogy with animals. The food taken up by the roots required no elaboration so as to separate the useful from the waste parts; this process had been effected, so Aristotle believed, by means of the soil and its heat. The plants received a food which corresponded with that which, in animals, passed from the stomach and small intestines into the blood. No waste products, so Aristotle says, were formed. This view was held for many centuries after

* *De Plantis*, Florence, 1583, p. 10. † *De Anima*, ii. c. 12, 424*a*.
‡ *P. A.* iv. c. 7, 683*b*. § *De Juvent. et Senect.* c. i, 468*a*.
‖ *G. A.* ii. c. 7, 745*b*. ¶ *De Gener. et Corr.* ii. c. 8, 335*a*.
** *P. A.* ii. c. 3, 650*a*, ii. c. 10, 655*b*.

Aristotle's time, but was disproved by Joachim Junge (1587–1657). In Cap. 2 of Fragment v., on the life of plants, in his *De Plantis Doxoscopiæ Physicæ Minores*, he says that plants have their own waste products, and asks who would assert that plants have the peculiar property of drawing from the soil that only which is suitable for their own material.*

Aristotle says that plants do not respire,† but it should be borne in mind that he did not believe that any living thing respired unless it had lungs. It was on this account that he held that fishes, crustaceans, molluscs, and many other animals did not respire. Anaxagoras, Diogenes, Democritus, and other ancient philosophers believed that all living things, or, at least, all animals, respired. This is asserted by Aristotle, when discussing the views of others on respiration.‡ Brisseau-Mirbel says that Anaxagoras believed that the leaves of plants absorbed and gave out the air.§ There does not seem to be any extant fragment of Anaxagoras which sets out the action of the leaves in this manner, but in the Aristotelian treatise, *De Plantis*, i. c. 2, it is stated that, according to Anaxagoras, plants also have πνοή, a breath or exhalation.

Aristotle says that plants are not affected by sleeping and waking (since they are without sense organs or sensation), but by what must be considered to be like sleep.‖ This is consistent with his belief that although plants have no sensation yet they are affected, as stated before, by certain influences. There is nothing to show that he was referring to the phenomenon of sleeping and waking, evidenced by the drooping and closing of flowers in the evening and their expansion in the morning.

According to Aristotle, there was no distinction of sexes in plants, but the male and female principles or powers were blended in them, so that they generated from themselves, the products of generation being the so-called seeds,¶ which were produced from the superfluous food of the plants.** Some plants, however, present a certain small difference like a sexual difference, for they do not bear fruit but contribute to the ripening of the fruit of other trees, such as, for

* *Joachimi Jungii Opuscula Botanica-Physica*, Coburg, 1747, p. 147.
† *De Anima*, i. c. 5, 410*b*. ‡ *De Respir.* c. 2, 470*b*.
§ *Élémens de Physiol. végét. et de Botanique*, Paris, 1815, p. 503.
‖ *De Somno, &c.*, c. i. 454*a* and *b*. ¶ *G. A.* i. c. 23, 731*a*.
** *P. A.* ii. c. 3, 650*a*; iv. c. 5, 681*a*.

example, the fig and the wild fig.* He explains more fully, in *H. A.* v. c. 26, s. 3, the action of the wild fig. In wild figs, according to him, is an insect called *Psen*, which, after passing through its larval and pupal stages, flies out and enters the unripe fruit of the cultivated fig trees. The effect produced is, so Aristotle says, that the figs do not fall off the trees, and, for this reason, the growers attach branches of the wild fig to the cultivated trees, and also plant the two kinds of trees close together.

This shows that he was aware of the custom of growers of figs to use branches of the Wild Fig (*Caprificus*) to effect the process, so well known by the name caprification, by which the growers believed that the ripening of the figs was hastened. The process of artificial fertilization of the date palm by applying the flowers of the male tree to those of the female tree was also practised by the Ancients, although they did not understand the process. The case of the fig was different, for both its male and its female flowers are carried by the inner parts of the hollow fleshy receptacle which forms the greater part of the fig. In this case, the beneficial result, if any, is believed to be due, just as Aristotle believed, to the piercing of the fruit by a kind of gall-insect (*Cynips*) carried by the branches of the wild fig.

Aristotle seems to have taken a very limited view of the functions of plants, for he says that they have no other duty but the production of seeds and fruit.† He states incorrectly that willows and black poplars do not produce seeds.‡ Some plants, he says, are fertile and others sterile.§

In what way Aristotle believed that the male and female principles or powers were blended in plants is not clear. His statement that some plants are fertile and others sterile indicates that he knew of the existence of what are now called diœcious plants, but it is also clear that he did not know that the sterile plants bore the male and the fertile ones the female flowers.

Aristotle came near to discovering that hermaphroditism which is found in the majority of flowering plants, but his views on the production of fruits and seeds prevented him from making the discovery. He seems to have been convinced that this production was the result of a process of nutrition. Plants, according to him, had a nutritive *soul* or

* *G. A.* i. c. 1, 715*b*.
† *Ibid.* i. c. 4, 717*a*.
‡ *Ibid.* i. c. 18, 726*a*.
§ *H. A.* iv. c. 11, s. 2.

vital principle only, and their fruits and seeds were a residue from the superfluous food of the plants. He held, it is true, that the male and female principles or powers were blended in some way in the plants, but he failed to discover the sexual importance of the stamens and pistils. The importance of these organs was not understood, in fact, until the seventeenth century, when Camerarius concluded that, in the vegetable kingdom, reproduction by means of seed is not effected unless the anthers (*apices*) have duly prepared the plant itself.* This conclusion was based on a number of experiments, *e.g.*, he observed that the castor-oil plant yielded empty capsules and not perfect fruits if the male flowers were removed before the anthers opened. Von Sachs says that all historic records concur in proving that Camerarius was the first who attempted to solve the question of sexuality in plants by experiment.†

Aristotle refers to parasitical plants, and says that these grow upon other plants, or may even be quite free, *e.g.*, a kind of Stonecrop (*Epipetron*) from Parnassus will grow for a long time when merely hung over a peg.‡ When describing the reproduction of bees, he says that some believed that they did not reproduce sexually but obtained their young from certain plants, *e.g.*, some kind of honeysuckle or reed.§ Again, he says that the *Chloris*, which was probably the greenfinch, made its nest of a plant called *Symphyton*, which it pulled up by the roots, and that its nest was lined with grass, hair, and wool.‖

In addition to those already mentioned, Aristotle also mentions, mostly in passages relating to the food of various animals, many other trees, shrubs, and herbs, some only of which can be identified at all satisfactorily, *e.g.*, species of oak, elm, almond, myrtle, rose, mistletoe, vetch, thyme, and various grasses. He mentions several plants from which, he says, bees obtain wax, *e.g.*, species of clover, lily, myrtle, and broom,¶ and several which are usually planted near the hives, *e.g.*, species of wild pear, bean, lucerne, poppy, myrtle, and almond.**

The above represents most of the work of Aristotle on plants, in so far as this has been preserved in his genuine

* *De Sexu Plantarum Epistola*, Tubingen, 1694, p. 40.
† *History of Botany from* 1530 *to* 1860, Garnsey's translation, Oxford, 1890, p. 385.
‡ *P. A.* iv. c. 5, 681*a*.
§ *H. A.* v. c. 18, s. 1.
‖ *Ibid.* ix. c. 14, s. 2.
¶ *Ibid.* ix. c. 27, s. 22.
** *Ibid.* ix. c. 27, s. 26.

writings. It has been mentioned already that he probably wrote a separate work on plants, but that no work on plants, which can be assigned with confidence to him, has been found. Such a work seems to be referred to by Athenæus and Pollux, for, referring to a certain kind of date without a stone, Athenæus says:—"And Aristotle speaks thus in his treatise on plants,"* while Pollux says:—"It is also written in the work of Aristotle or Theophrastus relating to plants."†

There is one and, apparently, only one work on plants which might be Aristotle's own, and this is the small Aristotelian treatise previously mentioned. There are several editions of it, the earliest which I have seen being one printed at the end of an edition of the *Geoponica*, usually attributed to Constantine VII., and published at Basle, in 1539, so it is believed. On the title-page is a statement in Latin, which reads:—"Also two Greek books on plants by Aristotle, which books have lately been saved from destruction and are restored for the first time in this edition for the use of the learned." In these books, plants are divided into trees, shrubs, grasses, and garden plants, such as cabbages, and also into house, garden, and wild plants; roots, bark, leaves, flowers, fruits, and other parts of plants are discussed, and also plants yielding milky juices and certain odoriferous plants of Syria and Arabia. It is also stated that plants grown in some localities become changed to other kinds when transferred to other localities, like a plant called *Belenion*, which is injurious when grown in Persia, but edible when transplanted to Egypt or Palestine, and reference is made to some date and fig trees which were said to be flowerless.

Referring to this treatise, Brisseau-Mirbel says:—"In the Middle Ages, an impostor dared to publish under the name of this philosopher a work entitled *De Plantis*, a crude collection of mistakes and absurdities, which nobody to-day attributes to Aristotle."‡ The mistakes and absurdities are not such, however, as to justify a belief that the work is spurious, and it must be conceded that, in accordance with Aristotle's own practice, there are repetitions, in substance at least, of statements found in his genuine works. These repetitions relate to the presence of a *soul* in plants, and the absence of sensation or motion, the distinction between

* *Deipn.* xiv. c 66. † x. 170.
‡ *Élémens de Physiol. végét. et de Botanique*, Paris, 1815, p. 505.

plants and animals by reason of the absence or presence of sensation, the want of a distinction of sexes in plants, the influence on plants of something which is not sleep, but is like sleep, and the primary or entire work of plants, *viz.*, the production of fruits and seeds. The treatise is also written in a truly Aristotelian manner, plain statements being made in a concise form. The evidence obtainable from a consideration of the particular style and Greek words and phrases used does not appear to be worth anything, for, in the preface to the treatise, it is stated :—"I have found much difficulty and also confusion of names because of frequent changes of translation from our language to Latin, then from Latin to Arabic, from Arabic again to Latin, and lastly from Latin to our language." It would be remarkable if any striking resemblance between the original Greek text, if any, and the *De Plantis* could be found after such a series of changes from one language to another, and, at best, the *De Plantis* can be only an imperfect version of such an original.

Further, the *De Plantis* is remarkable for referring to Plato specifically in its very first chapter, for a reference to Plato by name is very unusual in Aristotle's works and especially so in those relating to the Natural Sciences. In the *De Plantis*, Egypt, Æthiopia, Syria, Palestine, and Persia are referred to in a more familiar way than is usual in Aristotle's genuine works. Again, the passages referred to by Athenæus and attributed by him to Aristotle, *viz.*, one in *Deipn.* xiv. c. 66, relating to dates without stones, and another, in *Deipn.* xiv. c. 68, relating to grafted pears, do not occur in the *De Plantis*.

In conclusion, neither the evidence for nor that against the opinion that the *De Plantis* is a version of one of Aristotle's works is sufficient. The balance of evidence, however, goes to show that the *De Plantis* is spurious.

CHAPTER VIII.

THE PROBABLE NATURE AND EXTENT OF ARISTOTLE'S DISSECTIONS.

To the readers of Aristotle's zoological works, especially Books i.–iii. of his *History of Animals*, the question of the nature and extent of his dissections constantly presents itself. This question may be considered with respect to (1) the lower animals, and (2) Man, including the human fœtus.

With respect to the lower animals, Aristotle often speaks of the necessity for ascertaining the structure and arrangement of their parts by means of dissections. There are also many passages which clearly indicate the use of the dissecting-knife, *e.g.*, parts of the description of the chamæleon,* of the eyes of the mole,† and of the development of the chick in the egg.‡ Again, some of his descriptions of the internal parts of animals, *e.g.*, his description of the gall-bladder of the Pelamid,§ of the complex stomach of a ruminant,‖ and of the aorta and its branches,¶ indicate more than a laying open of the body of an animal and a casual inspection of its internal parts. There are also passages, *e.g.*, those describing the movements of the heart and sides of a chamæleon, after it had been dissected,** and that referring to the movements of the heart after its removal from a tortoise,†† which show that Aristotle vivisected some of the lower animals.

There are also statements which show that the dissections, if any, on which they were based were very carelessly performed, *e.g.*, the statements that the wolf and the lion have only one bone in the neck and not separate vertebræ,‡‡ and that the stomach of a dog or lion is not much wider

* *H. A.* ii. c. 7, s. 5.
† *Ibid.* i. c. 8, s. 3.
‡ *Ibid.* vi. c. 3, ss. 1–4.
§ *Ibid.* ii. c. 11, s. 7.
‖ *Ibid.* ii. c. 12, ss. 5–6.
¶ *Ibid.* iii. c. 4, ss. 3–6.
** *Ibid.* ii. c. 7, s. 5.
†† *De Juvent. et Senect.* c. 2, 468*b*.
‡‡ *P. A.* iv. c. 10, 686*a*; *H. A.* ii. c. 1, s. 1.

than the intestine.* Most of these statements were probably made by others and adopted by Aristotle without further examination, and, in any case, it would be unfair to estimate the value of his dissections by giving too much weight to such statements. His work on animals should be taken as a whole.

It is probable that Aristotle was taught dissection when quite young, for his father was one of the Asclepiads, an order of priest-physicians, who are said to have practised dissection and to have taught it to their children.† He must have made many examinations of the internal parts of mammals, birds, reptiles, and amphibians, to which he often refers, and his extensive knowledge of many cephalopods, molluscs, echinoderms, and fishes, must have been the result of numerous dissections. A list of animals which Aristotle appears to have dissected will be found at the end of this chapter. It is probable, from the way in which adverbs of position, such as ἔμπροσθεν and ὑποκάτω, are used in many passages, that Aristotle often dissected animals arranged in a vertical or at least highly inclined position.

With respect to human bodies, the chief question to be decided is whether or no Aristotle ever dissected one of these. In order to arrive at a conclusion, it is proposed to examine the evidence obtainable from Aristotle's writings, and then to examine the evidence furnished by the writings of other authors or by other sources of information.

After describing the external parts of the human body, Aristotle says that the internal parts are less known than those of other animals and that, in order to describe them, it becomes necessary to examine the corresponding parts of animals which are most nearly related to Man.‡ He also states that the human stomach is like that of a dog, and is not much wider than the intestine,§ that the occiput is empty,‖ and that the heart is above the lungs.¶ These passages clearly indicate that Aristotle never dissected a human body, and there are very few passages which suggest that he did so. His description of the position of the heart, in *H. A.* i. c. 14, ss. 1 and 2; ii. c. 12, s. 2, and *P. A.* iii. c. 4, 666*b*, has often been cited to show that he dissected the human body, but it is not by any means sufficient. On account of the importance of these passages in connection

* *H. A.* ii. c. 12, s. 7.
† Galen's *De Anat. Administr*, ii. c. 1.
‡ *H. A.* i. c. 13, s. 1.
§ *Ibid.* i. c. 13, s. 9.
‖ *Ibid.* i. c. 7, i. c. 13, s. 2.
¶ *Ibid.* i. c. 14, s. 1.

with the question of Aristotle's dissections, it will be necessary to discuss them at some length.

The heart, Aristotle says, is more to the left side in Man, being inclined a little away from the middle line, in the upper part of the chest, towards the left breast.* This is substantially correct, for about two-thirds of the volume of the heart lies to the left of the median plane and its apex is directed towards the lower part of the left breast. The description may have been written, however, after an examination of the position of the heart of one of the lower animals, supplemented by an external examination of the part of the human chest against which the heart seems to beat. It is evident that the beat of the heart, usually perceptible about three inches to the left of the median plane and in the fifth intercostal space, would suggest that the heart lies more on the left side of the chest. Galen says that it was on this account that the heart was believed to be on the left side; he himself believed that the heart was in a central position.†

Another passage sometimes cited to show that Aristotle dissected the human body is that in which he says that it is not without feelings of repugnance that we see blood, flesh, bones, blood-vessels, and other parts in the human body.‡ This passage seems to cut both ways; it is as much against as for the opinion that Aristotle dissected the human body.

It appears, therefore, that Aristotle's writings do not prove that he dissected the human body; on the contrary, they contain many statements which suggest that he never did so. With respect to the human fœtus, he seems to have dissected it, if only to a small extent. He says that if the human embryo, aborted after forty days, be put into cold water it becomes surrounded by a membrane, and that, if this be dissected away, the embryo appears to be of the size of a large ant, all its parts being visible and its eyes being large.§ Again, he makes some statements, *e.g.*, that the human kidneys are lobulated, which are true of the human fœtus.

Turning to the evidence obtainable from sources other than Aristotle's writings, it will be seen that there is a strong presumption against the probability that he ever dissected the human body. Among the Greeks a feeling of

* *H. A.* i. c. 14, s. 2, ii. c. 12, s. 2; *P. A.* iii. c. 4, 666*b*.
† *De Usu Partium*, vi. 2. ‡ *P A.* i. c. 5, 645*a*.
§ *H. A.* vii. c. 3, s. 4.

repugnance against mutilation of the human body and against any neglect of speedy burial was prevalent. The execution of the Athenian commanders after the Battle of Arginusæ, part of the charge being that they neglected to recover and bury some of the slain, and the attacks made at various time by orators against those who neglected to bury their deceased relatives, illustrate this. The agony of Antigone, the sad appeal of the shade of the unburied Patroclus, and the fervent wishes of many of Homer's heroes that their funeral rites might not be neglected accord well with the feelings of the Greeks. So strong were these feelings that it is unlikely that anyone could dissect a human body without exciting bitter feelings against himself. To meet this difficulty, some have held that Aristotle dissected the human body secretly. An assertion of this kind can neither be proved nor disproved.

Not many years after Aristotle's time, dissections of the human body were made at Alexandria, and Galen refers in many passages to dissections of this kind made by Erasistratus and Herophilus, about B.C. 280. These anatomists were followers of Aristotle, and their dissecting operations show that his oft-repeated advice about the importance of dissections did not fail to be effective. The anatomists of Europe were less fortunate than those of the Alexandrian Medical Schools; Galen's dissections were mostly made on Barbary apes, and, at a much later time, the anatomists of the sixteenth and seventeenth centuries experienced difficulties in obtaining human bodies for purposes of dissection.

From the above it may be concluded that Aristotle dissected many of the lower animals, and that, judged in relation to the anatomical knowledge of his time, his dissections were carefully performed. It may be said also that he dissected, to a small extent, the human fœtus, but that he did not further dissect the human body.

In various parts of his works, one or more of the internal parts of about one hundred and ten animals are described in sufficient detail to suggest that he dissected them. It is practically certain that he did not dissect some of these, *e.g.*, the hippopotamus and the crocodile, his knowledge of which seems to depend chiefly on Herodotus, but there are many for which definite information is given of so reliable a nature that it is fair to conclude that he dissected them. A list of these animals is given in the following table:—

Bat	Dove	Toad	Octopus
Deer	Duck	Conger	Sepia
Dolphin	Goose	Dogfish	Crab
Elephant	Owl	Eel	Lobster
Hare	Partridge	Fishing-frog	Murex
Horse	Pigeon	Grey Mullet	Purpura
Marten	Quail	Parasilurus	Snails
Mole	Swan	Pelamid	Whelk
Mouse	Chamæleon	Red Mullet	Locust
Ox	Grass Snake	Scorpæna	Sea-urchins
Pig	Lizard	Star Gazer	
Weasel	Tortoise	Ascidians	
Domestic Fowl	Frog	Calamary	

The inclusion of the elephant may cause surprise, but Aristotle's statements about it seem to justify its inclusion in the list.

CHAPTER IX.

ARISTOTLE'S HOMŒOMERIA.

The homœomeria are described chiefly in *H. A.* iii. cc. 2–17 and *P. A.* ii. cc. 1–9. It has been said that these parts of Aristotle's works bear some relationship to the science of Histology, but this is true only in a very limited degree. The science of Histology, in fact, cannot be said to have existed until Malpighi, Leeuwenhoek, and other investigators successfully used the microscope in the seventeenth century. How very slight the relationship is between Aristotle's work on the homœomeria and the science of Histology will be seen from the following descriptions of his common homœomeria, commencing with those included by him amongst the solid or dry and passing on to those included among the soft or liquid homœomeria. The former include bone, cartilage, sinew, "fibre" and the like, the material forming blood-vessels, skin and membrane, and the latter include flesh, suet and fat, marrow, blood, serum and the like, and milk.

1. *Bone and Cartilage.*—Aristotle says that the bones of viviparous quadrupeds with blood do not differ much in themselves, but merely in their relative degrees of hardness and softness, strength and weakness, and in the presence or absence of marrow.* He considered ordinary bone to contain more earthy matter than the bone found in fishes and, in *H. A.* iii. c. 7, s. 6, he says that the dolphin has ordinary bones and not bones like those of fishes, which are only analogous to ordinary bones.

He refers particularly to the hardness of the bones of lions, and says that they are harder than the bones of other animals, for, when struck together, sparks fly just as if the bones were stones.† It is true that many of the bones of lions are very hard. According to Owen, they contain 72·3 per cent. of inorganic constituents, or more than three

* *H. A.* iii. c. 7. s. 5; *P. A.* ii. c. 9, 655*a*.
† *H. A.* iii. c. 7, s. 6; *P. A.* ii. c. 9, 655*a*.

per cent. in excess of those found in the bones of Man and the ox.* Whether the bones of lions are harder than those of other animals would be very difficult to determine, but many of the bones of other carnivores are very hard, and so also are some of the bones of hares, rabbits, birds, and snakes.

Aristotle says that cartilage is of the same nature as bone, but differs in degree, and, like bone, does not grow after it has been cut away,† that in viviparous land animals it does not contain marrow in the same way as bones, and that it occurs about the ears, noses, and some extremities of bones in viviparous quadrupeds.‡

It is evident from these passages that he was aware of a close relationship between bone and cartilage, but there is nothing to show that he knew anything about the conversion of some cartilages into bone by ossifying processes. When he says that bone and cartilage differ in degree, he means that they manifest different degrees of certain qualities, such as, for example, hardness, strength, and heaviness.

In his statement about bone or cartilage not growing again, it is evident that he is not referring to a slicing or severance which still leaves the sliced or severed ends in contact; this is shown by his using the verb ἀποκόπτω (I cut or break off). A precisely similar statement is made twice in one of the genuine works of Hippocrates, the same verb being used.§ In all probability, Aristotle copied, in this instance, from Hippocrates. It is now known that, when a part of a bone or cartilage has been removed, the bone or cartilage is reproduced, provided the periosteum or perichondrium, as the case may be, has been left. Aristotle knew nothing of this, but he was aware of the importance of the periosteum in protecting the substance of the bone, for he says "bones which have been stripped bare of their membranes mortify."‖ In one of the genuine works of Hippocrates there is a passage which seems to show that mortification sets in when the membrane of a bone has been removed.¶

2. *Sinews, "Fibres," and the like.*—Aristotle repeatedly uses the words νεῦρον and ἶς (*neuron* and *is*) to denote certain constituents of the body. It is often difficult to determine

* *Anat. Vertebr.* vol. i. 1866, p. 20.
† *H. A.* iii. c. 8; *P. A.* ii. c. 9, 655*a*. ‡ *H. A.* iii. c. 8.
§ *Aphorisms*, Section 6, § 19 and Section 7, § 28.
‖ *H. A.* iii. c. 11, s. 1. ¶ *On Fractures*, § 33.

what these were intended to be, and he has often been misjudged through a careless or mistaken translation of these words. Considered as homœomeria, *neuron* refers chiefly to the material of which sinews, tendons, and ligaments are made, and *is* to the material of the fibrin of the blood, the fibre-like vessels containing a colourless fluid in many of the lower animals, and various fibre-like structures, such as small branches of the nervous system, and the connective tissues extending through the flesh.

Aristotle says that sinew is fissile longitudinally but not transversely, that it is very extensible, and that, when severed, it does not re-unite.* He also says that the fluid about the sinews is mucous, white, and gelatinous, and that the sinews are nourished by this fluid and seem to be produced from it.†

In the passages from Hippocrates, already referred to, it is stated that sinew does not re-unite after it has been cut.‡ It is probable that Aristotle copied this from Hippocrates. Plato's statements about sinews differ greatly from Aristotle's. He says that they are firmer and more glutinous than flesh, but softer and moister than bone, and that they are yellow and compounded in some way of bone and imperfectly formed flesh.§

Aristotle's statement concerning the fluid about the sinews is incorrect. The chief function of the synovial fluid is to lubricate the joints, and the fluid itself is probably a secretion, but may be, in part at least, a product of the frictional action between the surfaces of the joints.

The view sometimes expressed that Aristotle's neura were nerves will be discussed in Chapter xii.

Aristotle does not give any information of importance about the properties of his "fibres," excepting those which he believed were in the blood. These "fibres" will be more conveniently dealt with in the part of this chapter relating to the blood.

3. *Material forming the Blood-vessels.*—Aristotle misunderstood the nature of this material, for he considered what are now called the venæ cavæ, and probably some other veins, to be made up of skin and membrane, and the aorta to be very sinewy and its small branches to be quite sinewy.‖

* *H. A.* iii. c. 5, s. 3. † *Ibid.*
‡ *Aphorisms*, Section 6, § 19 and Section 7, § 28.
§ *Timæus*, 74. ‖ *H. A.* iii. c. 3, s. 3.

His attempts to describe the structure of these blood-vessels can hardly be expected to be satisfactory. He noticed, however, that the walls of the arteries were stouter than those of the veins, but his explanation is incorrect. The walls of arteries and veins are similar in structure, but there is a much greater development of muscular and elastic tissues in the inner and middle coats of the walls of the arteries than in those of the veins. In the passage already referred to, from *H. A.* iii. c. 3, s. 3, Aristotle probably uses the term *membrane* for the inner coat of the venæ cavæ, which is somewhat readily separable from the middle coat.

In *H. A.* iii. c. 5, s. 3, it is said that the material forming blood-vessels can resist the action of fire, while sinew is entirely destroyed by it. This statement is not altogether fanciful, for, when pieces of the aorta of an ox are cut off and placed on a bright red fire, except that they very slowly carbonize with the formation of small blisters and the oozing out of a small quantity of fluid, their forms undergo as little alteration as if they were pieces of porcelain. Under the same conditions, sinews are at once twisted into fantastic shapes and are carbonized more rapidly.

4. *Skin and Membrane.*—There is but little information, in Aristotle's works, about these materials. He considered skin (δέρμα) to be fissile and extensible, and membrane (ὑμήν) to be of the nature of a thin, compact skin, but neither fissile nor extensible.* He also says that membrane does not re-unite after it has been cut.† He includes the urinary bladder among membranes, but says that it is of a special kind, because it is extensible.‡

5. *Flesh.* — This is included by Aristotle among the soft or fluid homœomeria. Flesh, he says, is fissile in all directions,§ and is a material thrown down from the blood which, contained in numerous blood-vessels, is so universally distributed through the flesh that blood flows at once from any part of the flesh when cut, even though the blood-vessels cannot be seen in the cut parts.‖

In the Hippocratic treatise, *On Flesh*, §§ 8 and 9, it is explained how the liver, the kidneys, and the flesh are formed as a result of some kind of coagulation of the blood. It would seem, at first sight, that Aristotle had written his

* *H. A.* iii. c. 11, s. 1. † *Ibid.*
‡ *Ibid.* iii. c. 11, s. 3. § *Ibid.* iii. c. 12, s. 1.
‖ *P. A.* iii. c. 5, 668*a*.

statements about the formation of flesh, after consulting this Hippocratic treatise. It is admitted, however, that this treatise was not written by Hippocrates, but by an author of much later date. Plato also says that flesh is normally formed from the blood,* but his real meaning is not clear, for he says that bone, flesh, and the like are all formed from marrow and other materials.†

Aristotle does not appear to have known anything about that most remarkable property of flesh, *viz.*, its contractility. This will be discussed in Chapter xiii. His reference to "fibres" and the like seen in flesh show that he saw, but did not understand the nature of, the connective tissues which ensheath the muscle-bundles.

6. *Suet and Fat.*—Aristotle says that suet is quite hard and brittle when cold, but fat is liquid and does not harden, and that they differ with respect to the parts in which they occur.‡ Both suet and fat are formed, according to him, from blood, and, on this account, he concluded wrongly that fat is not found in animals without blood.§

Aristotle's statement that fat is liquid and does not harden is true of some animals only. The comparatively large masses of fat in geese, ducks, and quails are nearly or quite liquid in the living birds, and the fat of the quail runs like water at as low a temperature as 50° or 60° F. The fat of fishes and amphibians is also fluid at comparatively very low temperatures. The fat of some animals melts at comparatively high temperatures and, even in animals like pigs and horses, in which the fat is of a soft kind, it is not liquid in the living animals.

7. *Marrow.* — In *P. A.* ii. c. 6, 651*b*, Aristotle says: "Marrow is of the nature of blood and is not, as some believe, the active generating force of semen." This is a refutation, more particularly of one of Plato's statements in the *Timæus*, 73. It is contained, he says, in the bones, and is quite full of blood in young animals, but is either fatty or suety in older animals.‖

In very young animals the marrow is red and vascular, and in older animals there are the ordinary yellow marrow, rich in fats, and the red marrow found in the ribs, sternum, vertebræ, cranial bones, and the epiphyses of the long bones. This red marrow contains less fat, but many small

* *Timæus*, 82. † *Ibid.* 73.
‡ *H. A.* iii. c. 13, s. 1. § *P. A.* ii. c. 5, 651*a*.
‖ *H. A.* iii. c. 15.

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red cells, or erythroblasts, which are concerned in the production of the red corpuscles of the blood.

8. *Blood, Serum, and the like.*—Aristotle paid much attention to these homœomeria. He gives a great deal of interesting information about the blood, the serum or watery part of it, and the process of coagulation. He says that normally healthy blood contains a sweet juice and is of a red colour, and that blood which is dark in colour, either naturally or as a result of disease, is inferior to that which is of a red colour.* It is true that there is a very small quantity of dextrose in blood, but this is not apparent to the taste, the blood being slightly salt.

Aristotle believed, as has been stated in Chapter iv., that blood was not an essentially hot liquid, but derived its heat from the heart, at least to a large extent. Comparing the blood of Man with that of some other animals, he says that Man has the brightest and thinnest blood, and that the ox and the ass have the darkest and thickest.† The colours of arterial blood in Man, the ox, and apparently the ass, differ very little from one another, and the same is true of the colours of the venous blood. The arterial blood of the pigeon and many other birds is lighter than that of Man or the ox. With respect to Aristotle's statement about the relative consistency of the blood in Man and the ox, it appears from Thackrah's experiments that the blood of the ox is thinner than that of the pig or dog, and not thicker than that of Man.‡ Aristotle says that the blood which supplies the brain is small in amount and pure.§ In most animals the supply of blood to the brain is large, but Aristotle's statement is quite in accordance with several statements he makes about the brain, in which, he says, no blood-vessel is to be seen. Further, the blood supplied to the brain in Man and other mammals and in birds is scarcely, if at all, purer than that supplied to other parts. It is true, however, that in the Batrachia, Ophidia, Lacertilia, Chelonia, and, to a less extent, the Crocodilia, the structure of the heart and arrangement of the main blood-vessels are such that the purest blood is sent to the brain.

There are several passages in his works showing that Aristotle noticed differences, or what he thought were

* *H. A.* iii. c. 14, s. 1. † *Ibid.* iii. c. 14, s. 3.

‡ *An Inquiry into the Nature and Properties of the Blood*, &c., Wright's edition, 1834, pp. 154 and 236.

§ *P. A.* ii. c. 7, 652*b*.

differences, in arterial and venous blood now so called, although he did not understand the causes of these differences. In *P. A.* ii. c. 2, 647*b*, he points out that differences in consistency, clearness, and temperature are noticeable in blood taken from different parts of the same animal. Again, after referring to the existence of two main blood-vessels, one being the aorta and the other including the venæ cavæ, and pointing out that these vessels are different in character, he says that it is better that each should have its own blood supply, and that the blood of one side of the body should be distinct from that of the other.* He also says that the blood in the right cavity of the heart and that of the right side of the body is hotter than the rest of the blood.†

The differences in consistency, colour, and apparent purity, to which he alludes in these passages, would be evident to his senses, but it is not clear how he decided that there were differences of temperature, for such differences as exist are very small. It is probable that his views about the relative temperatures of the blood in different parts of the body were dependent on his belief that the right side is more honourable than the left side, the upper part than the lower part, and the front than the back.

Aristotle's statements about the coagulation of the blood are numerous and interesting, but before discussing them, the views of Plato, in particular, on this subject should be considered, in order to ascertain to what extent Aristotle's views were original. Plato, whom Aristotle does not cite, says that the "fibres" cause the blood to coagulate when it has been drawn from the body and allowed to cool, and that, by the nature of their composition, they maintain the blood at a proper degree of consistency, so that it does not become liquid enough to flow through the porous structures of the body, nor so sluggish as to flow with difficulty through the blood-vessels.‡ He also speaks of serum (ἰχώρ), and calls it the watery part of the blood.§ In the genuine works of Hippocrates there is nothing worthy of mention on the coagulation of the blood. There is an important passage in the Hippocratic treatise *On Flesh*, § 8, which states that blood coagulates on cooling, and that the "fibres" are of a cold nature and glutinous. This work, however, is generally believed to have been written long after the time of Hippocrates.

* *P. A.* iii. c. 4, 666*b*.
† *Ibid.* iii. c. 4, 667*a*.
‡ *Timæus*, 85.
§ *Ibid.* 83.

It has already been pointed out, in Chapter i., that it is very difficult to decide to what extent Aristotle was indebted to Plato on subjects of this kind, but on the subject of coagulation of the blood it is clear that Plato knew the main facts recorded by Aristotle. On the other hand, Aristotle does not seem to have obtained anything from Hippocrates on this subject. When modern writers state, as many have stated, that Aristotle obtained many ideas from Hippocrates, the distinction between the genuine works of Hippocrates and works written by his followers ought to be borne in mind. Some of the Hippocratic treatises were written after the time of Aristotle.

Blood, Aristotle says, has a watery portion, called ἰχώρ,* and, in the blood of most animals, there are certain "fibres," called ἶνες.† Blood does not coagulate when these fibres have been removed from it.‡ The coagulation of the blood takes place, he says, not in the watery part but in the earthy part, during the evaporation of the watery part.§ Blood, according to him, is composed of earthy and watery parts, and needs a certain amount of water to keep it liquid and also a certain amount of heat, and therefore it can be coagulated by heating so as to evaporate the water and by cooling so as to drive off heat together with watery vapour.‖ He believed also that some animals had a hasty temper in consequence of the many "fibres" in their blood, and he explains that the "fibres" are like so many hot embers in the blood, and act like the hot embers of a vapour bath.¶

The above passages show clearly that Aristotle considered that blood had two constituents at least, *viz.*, serum and certain fibres which correspond with what is now called fibrin and is readily separable from blood by beating it with a twig. He gives but little information about the nature of the fibres themselves. It is clear, however, that he believed that they were solid bodies of a hot nature existing in the blood of the living animal. These solid bodies, according to him, constituted the blood clot, when the blood was coagulated. His explanation of the process of coagulation by cooling so as to get rid of heat and water does not take account of the fact that the clot forms as a separate mass in a large quantity of serum, only a very small quantity of water passing away during the cooling. That fibrin is

* *P. A.* ii. c 4, 651*a*.
† *Ibid.* ii. c. 4, 650*b*; *H. A.* iii. c. 6.
‡ *H. A.* iii. c. 6.
§ *P. A.* ii. c. 4, 650*b*.
‖ *Meteorol.* iv. c. 7, ss. 10–13.
¶ *P. A.* ii. c. 4, 650*b* and 651*a*.

formed after the blood has been drawn from the body, and that this fibrin has a tendency to form meshworks in which rolls of red blood corpuscles, like rolls of coins, are entangled, and that the fibrin and corpuscles form the chief part of the blood clot, are facts which were not ascertained until many centuries after Aristotle's time.

The blood of oxen, Aristotle says, coagulates more quickly than that of other animals, and the blood of the deer, roe, and *Boubalis*, probably the Bubaline Antelope, does not coagulate.* In another passage, in *H. A.* iii. c. 6, a somewhat different statement is made, for he says that "fibres" do not occur in the blood of the deer, roe, and *Boubalis*, and the blood of these animals does not coagulate like that of other animals, but the blood of the deer coagulates like that of hares, the clot not being firm, while the blood of the *Boubalis* coagulates to a greater degree, for it thickens almost as much as that of sheep.

According to Thackrah's experiments, the blood of the ox does not coagulate more quickly than that of other animals. These experiments showed that the blood of the ox begins to coagulate in from two to ten minutes, that of the sheep, pig, or rabbit in from one to two minutes, and that of the horse in from five to thirteen minutes.†

Fibrin is formed in the blood of the deer, roe, antelope, and most other, if not all, mammals, but it is not normally present in the living body. Aristotle thought that the blood of the deer, the one specially referred to being the red deer (ἔλαφος), and that of the *Boubalis* coagulate, but that the clot was soft. When describing various causes which prevent blood from coagulating, John Hunter says: "Two deer were hunted to death . . . . On opening them, the blood was fluid, only a little thickened, and the muscles were not rigid."‡ It is known that the blood of hunted animals coagulates, but only imperfectly, and, as the animals mentioned by Aristotle are such as are commonly hunted, it is probable that he is referring to the imperfect coagulation of the blood of animals hunted to death. The blood of deer which have not been hunted to death coagulates in the usual way, a fact clearly stated by Redi.§

* *H. A.* iii. c. 6, iii. c. 14, s. 2; *P. A.* ii. c. 4, 651*a*.

† *Op. cit.* p. 154.

‡ *The Works of John Hunter*, edited by James F. Palmer, 1835–37, vol. i. p. 239.

§ *Exper. circa res Divers. Natural.* 1675, p. 160.

Aristotle believed that ferocity and liability to fits of passion were dependent in some way on the quantity of "fibres" in the blood. According to him the "fibres" are earthy and solid, and, acting like the hot embers in a vapour bath, cause ebullition in the blood, this being the reason why oxen and boars are so passionate, for their blood is rich in "fibres."* The animals mentioned in *H. A.* iii. c. 6, *viz.*, the deer, roe, antelope, hare, and sheep, are usually considered to be timid, and Aristotle evidently thought that they had but few "fibres" in their blood, compared with those in the blood of the ox or boar.

Thackrah's experiments support Aristotle's view that the ferocity of an animal depends, in some way, on the quantity of "fibres" in the blood. After making numerous experiments he concluded thus: "I never found the serum in such quantity as in the timid sheep, nor the crassamentum so abundant as in the predatory dog." †

9. *Milk.*—All milk, Aristotle says, consists of a watery fluid, which is called whey, and a thicker part, called curd, the thicker kinds of milk containing more curd than other kinds.‡ He also says that the milk of the camel is thinnest, then that of the mare, and then that of the ass, but cow's milk is thicker.§ There is a fatness in milk, he says, which causes it to become oily when the milk has been coagulated or thickened.‖ In cows' milk there is more curd, he says, than in goats' milk, for the herdsmen say that they make from about nine gallons of goats' milk nineteen cheeses, each worth an obolos, and thirty from cows' milk.¶

The above are the chief statements made by Aristotle about the nature and composition of milk. He gives correctly the relative degrees of consistency of the milk of the cow, ass, and mare, but his statement about camel's milk is incorrect. Camel's milk is nearly, if not quite, as thick as cow's milk, and contains a little less water and casein, more sugar, and about as much fat as the latter. The assertion in *H. A.* iii. c. 16, s. 5, is difficult to understand. Average samples of cows' milk and goats' milk contain nearly the same amount of casein, that in goats' milk being, if anything, the larger. The Greeks, it may be mentioned, did not esteem cows' milk for making cheese, goats' milk having been used most by them.

* *P. A.* ii. c. 4, 650*b* and 651*a*.
† *Op. cit.* p. 154.
‡ *H. A.* iii. c. 16, s. 2.
§ *Ibid.*
‖ *Ibid.* iii. c. 16, s. 5.
¶ *Ibid.*

The coagulation of milk, Aristotle says, is effected both by rennet and the juice of the fig.* He states incorrectly that rennet is a kind of milk, and that it is obtained from the third stomach of sucking animals.†

Rennet is obtained from the fourth stomach of ruminants and, in comparatively smaller quantities, from the stomachs of most, if not all, mammals. Rennet is usually an infusion of the dried fourth stomach of a calf, and owes its coagulating properties to the presence of a ferment occurring in the gastric juice. Aristotle believed that the hare was the only animal, other than ruminants, which yielded rennet, and that the rennet from the fawn was the best.‡

* *H. A.* iii. c. 16, s. 6. † *H. A.* iii. c. 16, s. 6; *P. A.* iii. c. 15, 676*a*.
‡ *Ibid.*

CHAPTER X.

ARISTOTLE'S ANHOMŒOMERIA AND THEIR FUNCTIONS.

It has been explained already, in Chapter vi., that Aristotle's anhomœomeria were, generally speaking, organs or parts having definite forms or functions. His descriptions of these anhomœomeria are very incomplete, and vary much in value, a few, *e.g.*, the blood-vessels, being described at great length, while others are described in very general terms, and some important anhomœomeria are merely mentioned, or not referred to at all. On the other hand, some interesting details are given about structures, which are not generally known, such as, for example, certain bones in the hearts of horses and oxen. His anhomœomeria are described chiefly in *H. A.* i. cc. 7–14, ii. cc. 8–12, iii. cc. 1–11, and *P. A.* ii.–iv., and these parts of his works contain most of his extant writings on comparative anatomy.

In the following descriptions, his most important statements about the various anhomœomeria, except the locomotory organs, which will be dealt with in Chapter xiii., will be discussed, and, when discussing any particular set of structures, those of Man will be taken first and then those of other mammals, and of birds and other animals.

A.—Skeletal and Epidermal Structures.

a. *Bones and Cartilages.*—Aristotle describes the bones of the human head rather fully, while he does little more than mention and indicate the relative positions of other parts of the human skeleton. For other animals, his descriptions are limited to a few bones, *e.g.*, the ribs, the astragali, and the pelvis. He gives but little information about the cartilages.

He did not consider the fore part of the frontal bone to be part of the human cranium, which he defined to be the part of the skull covered by hair, the forehead being a part

of the face.* According to Aristotle, the front part of the cranium, the sinciput, is developed after birth and is the last bone of the body to harden.† He erroneously believed that the back part of the head, the occiput, was full of air.‡ This statement will be briefly discussed in Chapter xii.

Aristotle says that the cranium of Man has six bones, and that two of these are situated about the ears, and are small compared with the others.§ He also says that they are connected by sutures, three usually running into one another in triquetrous manner, in men, and one running round the skull, in women, but that a man's skull had been seen without sutures.‖

The six bones referred to above are the occipital, the parietals, the temporals, and part of the frontal. Aristotle's description of the sutures is incomplete and incorrect. Generally the number and arrangement of the cranial sutures is the same both in men and women. Looking down on the top of a normally developed adult skull, the sagittal suture and the right and left halves of the coronal suture are seen to converge to a point. The description may refer to these, or, assuming the skull to be viewed in back elevation, it may refer, in a similar way, to the sagittal and lambdoid sutures. The chief variations of the sutures are due to their partial obliteration and the presence of a frontal suture continuous with the sagittal.

Of the few ancient writers who have described the cranial sutures, not one seems to have correctly explained their arrangement. Hippocrates says that it depends on the relative development of prominences at the front and back of the head, and compares the various arrangements to the letters or symbols T, ⊥, ⊥, and X ¶. Galen's description, in his *On the Use of Parts*, ix. 7, is similar to that given by Hippocrates.

Aristotle's statement that a man's skull without sutures had been seen was probably taken from *Herodotus*, ix. 83, where it is said that, after the battle of Platæa, a skull without sutures and all of one bone was found. The sutures become indistinct in the skulls of old people, but a cranium without sutures is very rarely seen. Instances of obliteration of cranial sutures seem to be most common

* *H. A.* i. c. 7 and c. 8, s. 1. † *Ibid.* i. c. 7.
‡ *Ibid.* i. c. 7, i. c. 13, s. 2; *P. A.* ii. c. 10, 656*b*.
§ *H. A.* iii. c. 7, s. 2. ‖ *Ibid.* i. c. 7, iii. c. 7, s. 2.
¶ *On Wounds in the Head*, c. 1.

among Negroes. Two skulls of this kind, with the coronal, sagittal, and parts of the lambdoid sutures nearly or quite obliterated, may be seen at the Natural History Museum, South Kensington. These skulls came from Ashanti and from near Izavo, British East Africa, respectively.

No information of any importance about the other bones of the head is given by Aristotle, nor is any information worthy of note given by him about other bones of the human body, other than the ribs. He says : " On each side of the body are eight ribs belonging to the upper and lower parts of the trunk, for I have not heard anything worthy of credit about the seven-ribbed Ligurians." *

Usually there are twelve ribs on each side of the human body, the eleventh and twelfth being unconnected to the sternum. It is not at all clear which are the eight ribs to which Aristotle refers, or why he does not take account of the remaining ribs. The Ligurians were short but strong and brave people, who lived in a strip of maritime country extending from the mouth of the Rhone to Pisæ, in Etruria. Schneider says, in his note on *H. A.* i. c. 10, s. 6, that the tale of the fewer ribs of the Ligurians probably had an origin similar to that current among some people about the ribs of animals, *e. g.*, some Carniolans assign more ribs to the larger or better breeds of sheep. It may be mentioned that, in Man, an increased number of ribs is sometimes found, and, less frequently, a reduced number.

Aristotle says that no animal with many toes, *e. g.*, Man, has astragali or knuckle-bones.† Man has astragali, but they are very unsymmetrical and would therefore be neglected by Aristotle. This will be further explained later in his description of bones and cartilages.

In *H. A.* iii. c. 7, s. 2, it is stated that the cranium is not made in the same way in all animals, for it is formed in a single bone in some, such as the dog. This is true of the craniums of very old dogs, and some other animals, in which the sutures become obliterated.

Aristotle makes the erroneous statement, in more than one passage, that the crocodile moves its upper jaw, and is the only animal which does so.‡ The assertion was probably copied from *Herodotus*, ii. 68, but Aristotle proceeds to give a remarkably ingenious explanation. He says that the crocodile's feet are so small that they are useless for

* *H. A.* i. c. 10, s. 6. † *Ibid.* ii. c. 2, s. 10.
‡ *H. A.* i. c. 9, s. 6, iii. c. 7, s. 3 ; *P. A.* iv. c. 11, 691*b*.

seizing and gripping prey, but Nature has provided the crocodile with a mouth of such a kind as to compensate for this defect. A downward blow, he says, is more powerful than one delivered upwards, and so also a downward motion of the upper jaw is more effective for seizing and holding prey than an upward movement of the lower jaw.* The fact that the crocodile's lower jaw is moved is liable to escape notice chiefly because it extends some distance behind the head.

In the neck of the lion and of the wolf, Aristotle says, there is, for the sake of strength, only one bone.† These passages have been specially cited by some writers to show that Aristotle made anatomical observations carelessly. It would be more correct to say that, with respect to the passages referred to, he made no anatomical observations at all, but merely expressed a popular belief.

Aristotle gives but little information about the backbone of animals. To account for the great mobility of snakes, he says that their vertebræ are cartilaginous and easily bent.‡ The vertebræ of snakes are made of hard bone, and they are numerous and loosely connected by means of ball-and-socket joints. For these reasons the backbones of snakes are very flexible. It is very probable that Aristotle never examined the skeleton of a snake, for, in another passage, he says that a snake has thirty ribs.§ Further, his statements about the backbones of snakes are not consistent, for, in *H. A.* iii. c. 7, s. 7, he says that they have a spinous backbone, like that of a fish.

Speaking of the chamæleon, he says that its ribs, which unite together, extend downwards towards the middle line of its abdomen, as in fishes.‖.

Except when agitated and puffed out with air, the chamæleon has deep sides and a laterally compressed body, not unlike that of many fishes. Numerous thin ribs run down to the sternum, and, behind these, some pairs of long and very thin ribs meet ventrally and form a series of hoops. The chamæleon is one of the animals with which Aristotle was well acquainted, and it is practically certain that he dissected it.

Aristotle says that, in the flat cartilaginous fishes, there is, in the position of the vertebral column, a cartilage taking

* *P. A.* iv. c. 11, 691*b*. † *H. A.* ii. c. 1, s. 1; *P. A.* iv. c. 10, 686*a*.
‡ *P. A.* iv. c. 11, 692*a*. § *H. A.* ii. c. 12, s. 12.
‖ *Ibid.* ii. c. 7, s. 1.

the place of bones, and containing a marrow-like liquid.* This is probably a reference to the biconical masses or remains of the notochord, which extends through the cartilaginous centre, but exists in the long as well as the flat cartilaginous fishes.

While dealing with cartilages, it may be stated that Aristotle was aware of the existence of cartilages at the ends of some bones, but he did not understand the relationship between them, and he erroneously speaks of the external generative organs of some animals as if they were cartilaginous.†

Aristotle did not believe that the seal had a humerus, for he states that it has stunted feet,‡ and that it is, as it were, a stunted animal, because its fore feet are just behind its shoulder-blades.§ The seal with which he was acquainted was that now called the Monk Seal (*Monachus albiventer*).

In *P. A.* iv. c. 12, 693*b*, Aristotle says that the inner extremities of the wings of birds rest on their backs and take the place of shoulder-blades, and that the breast-bone is sharp-edged in all birds to facilitate their flight. It is clear, therefore, that he did not recognize the presence of a true shoulder-blade in birds. He knew of the existence of the ostrich, but did not know anything of the form of its breast-bone.

The "ischion" of a bird, according to Aristotle, is like a thigh-bone, being long and attached in some way as far as the middle of the abdomen, so that, when separated, it might be taken for the thigh-bone, and the "thigh-bone," between it and the leg, to be some other bone.‖ He considered the "ischion," running along and hidden to a large extent within the abdomen, to be like a thigh-bone, whereas it is the thigh-bone; on the other hand, he considered the leg proper to be the thigh, and the shank or tarsus to be the leg.

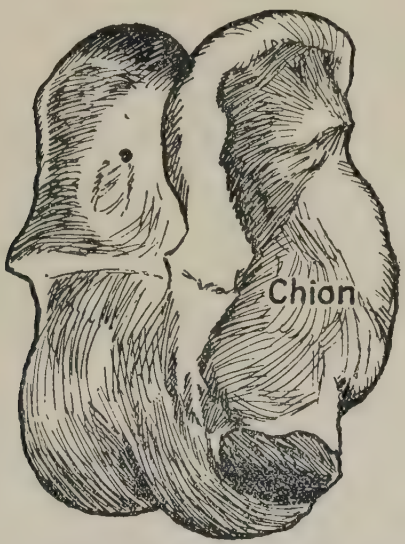
This explanation of his views agrees with certain important statements made by him. He states that, although birds are bipeds, they cannot stand erect, and that they are enabled to stand as they do by reason of their "ischia" being long and extending forwards along the abdomen, so as to bring the legs to or near the centre of the bird's body.¶ He also says that the "ischion" is like a thigh and of such

* *H. A.* iii. c. 8.
† *Ibid.* i. c. 10, s. 4.
‡ *Ibid.* i. c. 1, s. 9.
§ *Ibid.* ii. c. 1, s. 7.
‖ *Ibid.* ii. c. 8, s. 1.
¶ *P. A.* iv. c. 12, 695*a*.

a length that a bird seems to have two thighs, one next the shank and the other, the "ischion," extending from the rump to the aforesaid thigh.* Further, he says that birds have sinewy and not fleshy legs.† Some consider the "ischia" of birds to be the pelvic bones, but this explanation makes Aristotle's statements very difficult to understand.

The astragali, or knuckle-bones, which chiefly transmit the downward thrust of the tibial bones, are often referred to by Aristotle. Those only which were elegant or fairly

FIG. 6.



LEFT ASTRAGALUS OF A SHEEP.

symmetrical were used by the Ancients in playing various games and for divination, and it is only to such astragali as these that Aristotle usually gave the name. It was on account of want of symmetry that he excluded Man and most animals with many toes from among animals having astragali, although he refers to the twisted knuckle-bone of the lion, and calls the unsymmetrical and comparatively long and thin knuckle-bone of the lynx a half astragalus.‡ He says that most of the animals with astragali are cloven-

* *De Anim. Incessu.* c. 11, 710*b*.
† *H. A.* ii. c. 2, s. 7; *P. A.* iv. c. 12, 695*a*.
‡ *H. A.* ii. c. 2, s. 10.

footed,* that the astragali are always in the hind legs and are arranged upright in the joints, so that the front parts are [inclined] outwards and the back parts inwards, and that the coa are turned inwards towards each other and the so called chia outwards, the "horns" being upwards.†

Applying this description to the astragali of an animal, such as a sheep, the comparatively flat narrow sides, which are on the inner sides of the legs and face each other are the coa, and the indented or ear-like faces are the chia. Fig. 6 (which is twice the natural size) shows the chion and front broad face of the left astragalus of a sheep. Some say, however, that the flat sides are the chia and the indented sides the coa. The values usually given to the faces were as follows:—Cöon, six; chion, one; front broad face, four, and back broad face, three; the bottom face was counted and not, as in the modern method of playing dice, the top face. The values had no apparent connection with the probabilities of the throws, *e. g.*, in five hundred throws of a sheep's astragalus, the indented side was beneath in fifty-one and the flat side in forty-two throws.

In addition to the lion and the lynx, Aristotle refers specifically to the knuckle-bones of the hippopotamus, camel, pig, ox, and a mythical animal, the Indian ass, having solid hoofs and one horn.

He says that the knuckle-bones of a camel are like those of an ox, but ugly, and small in proportion to the size of the animal.‡ This comparison tends to show that he saw the knuckle-bones of both these animals. A camel's knuckle-bones, which may be seen in the articulated skeleton at University Museum, Oxford, have a marked general similarity to those of an ox, but their lower ends are less symmetrical. They are also small in proportion to the size of the camel.

It is evident why Aristotle paid so much attention to the knuckle-bones. No other bones had more interest for the Ancients than these. Knuckle-bones of sheep or goats have been found in a tomb in Ithaca, and these and many artificial ones of bronze, lead, agate, and rock-crystal may be seen at the British Museum, as well as an Æginetan vase of black ware in the form of a knuckle-bone. Among the terra-cottas in the Museum are a figure of a girl (C 715)

* *P. A.* iv. c. 10, 690*a*. † *H. A.* ii. c. 2, s. 10.
‡ *H. A.* ii. c. 2, s. 5.

playing with knuckle-bones, from Cyrenaica, and a beautiful group of astragalizontes (D 161), from Italy, while among the marble statues are a female player (1710) and two boys quarrelling over a game (1756), both found in Rome. References are made, both by ancient and modern writers, to the use of golden astragali by the Ancients, but I have not been able to obtain any reliable information about the discovery of any of these in modern times. To-day the use of knuckle-bones for divination or dice-playing is almost universal, being found among widely different peoples, such as the Barotse in South Africa, the Baloches, and the American Indians.

The bones dealt with so far are of quite an ordinary and well-known kind; it is proposed to deal next with two kinds

FIG 7.

BONES FROM THE HEART OF A 3-YEAR OLD OX.

which are not commonly known, *viz.*, the bones of the hearts of some animals, and the *os penis* found in the weasel and some other animals.

In *H. A.* ii. c. 11, s. 3, and *P. A.* iii. c. 4, 666*b*, it is stated that in horses and a certain kind of ox a bone is found in the heart and serves as a support. In oxen, a long curved bone is embedded circumferentially in the very root of the aorta and in the auricular end of the partition between the ventricles, and a much smaller bone, of triangular shape, is found in that part of the root of the aorta which is diametrically opposite to the large bone. Fig. 7 (which is twice the natural size) shows these bones, in side elevation, taken from the heart of a three-year old ox.

They seem to occur in all oxen; at any rate, they occurred in all ox hearts which I have dissected. Bones are also said to occur in the hearts of some horses, deer, elephants, and some other animals.

In *H. A.* ii. c. 3, s. 5, it is stated that some animals, *e.g.*, the fox, wolf, weasel, and marten, have a bony penis, and that of these the marten certainly has one. Many mammals have a bone, sometimes quite small, in the penis. Such a bone is found, *e.g.*, in the rat, mouse, guinea-pig, monkey, and ape, and in the weasel, marten, and many other carnivores, but not in the fox and wolf. In a large stoat which I dissected the bone was slender and curved, and about one inch long.

The feet of pigs are almost always cloven, but in various countries and at different times instances of syndactylism have occurred. Aristotle seems to have been the first to record phenomena of this kind. He says: "There are pigs with solid hoofs in Illyria, Pæonia, and other places." * The syndactylism affects the third and fourth digits, the lateral toes being developed, apparently in all cases, in the usual way. Several instances might be given, but the following will be sufficient. A solid-hoofed sow, received in November, 1876, at the Zoological Gardens, from Cuba, gave birth to a litter of six, three of which were also solid-hoofed. One of these died, and it was found that the extreme distal ends of its ungual phalanges were completely fused together.† Solid-hoofed pigs are said to have been well known and abundant about the year 1823 on the estates then belonging to Sir Neil Menzies, of Rannoch, Perthshire.‡ Usually, the digits are not united throughout their length; in fact, Mr. Bateson says that the only case known to him of complete union of the third and fourth digits, there being only a single series of bones, is in the Museum at Alfort.§

Aristotle erroneously believed that the bones of the lion, pig, and some other animals either contained no marrow at all or only a little, and this only in a few bones, *e.g.*, the humerus and femur.‖ In the lion there are distinct marrow cavities, not only in the humeral and femoral bones, but also in the radial, tibial, metacarpal, and metatarsal bones. The

* *H. A.* ii. c. 2, s. 8. † *Proc. Zool. Soc.* 1877, p. 33.
‡ *Edin. New Philos. Journ.*, vol. 17, pp. 273–279.
§ *Materials for the Study of Variation, &c.*, 1894, p. 387.
‖ *H. A.* iii. c. 7, s. 6, iii. c. 15; *P. A.* ii. c. 6, 651*b*.

marrow is not small in quantity, although an examination of the fractured long bones of lions shows that the cross-sectional areas of their marrow cavities are relatively smaller than those of corresponding bones of the ox, deer, and many other animals. Again, the long bones of the pig have a rather large amount of marrow, *e.g.*, the femoral bones commonly have a marrow cavity more than half an inch in diameter.

b. *Skeletal Structures of Aristotle's Anaima.*—Some of the skeletal structures of the *Anaima*, or animals without blood, are described very briefly in *H. A.* iv. cc. 1–7, and *P. A.* iv. c. 5.

Aristotle speaks of the cuttle-bone of *Sepia* and the pen of *Loligo*, saying that each is found in the dorsal part of the body, that the pen is thin and somewhat cartilaginous, that the cuttle-bone is strong and broad, of a nature between that of bone and that of fish-spine, and that it is spongy and friable within.*

Aristotle's descriptions of the materials of these internal structures is faulty, cuttle-bone being calcareous and the pen horny, but in other respects his statements are substantially correct.

The external parts of crustaceans, he says, are not brittle, but are of a tough nature; those of his *Ostrakoderma*, such as snails and oysters, are hard and brittle, and the external parts of his *Entoma* are neither harder nor softer than their internal parts.† These statements are fairly clear, except with respect to the *Entoma*, for Aristotle included among these such animals as scorpions, beetles, centipedes, and millipedes, the external parts of which are often very hard.

He also describes the external coverings of some of the ascidians, saying that they are of a nature between those of skin and shell and can be cut like leather.‡

Aristotle compares the perforated shell of the sea-urchin, when divested of its skin, to a lantern.§

c. *Teeth and Horns.*—Aristotle considered the teeth to be very hard bones. He says: "In the jaws are the teeth, the bone of which is partly solid and partly hollow. The bones of the teeth are the only ones which cannot be engraved." ‖ This is clearly a reference to the enamel.

In several passages Aristotle deals with the relationship

* *H. A.* iv. c. 1, s. 12.
† *Ibid.* iv. c. 1, ss. 2 and 3.
‡ *Ibid.* iv. c. 6, s. 1.
§ *Ibid.* iv. c. 5, s. 6.
‖ *Ibid.* iii. c. 7, s. 3.

between teeth and horns. He was aware, in fact, of the existence of an inverse relationship between the degrees of development of teeth and horns, such as that referred to and exemplified by Owen.* Aristotle says that no animal has both tusks and horns, nor sharp, interlocking teeth and tusks or horns,† and that, in the larger animals, there is an excess of earthy matter, which is utilized in the formation of defensive weapons, *e.g.*, tusks and horns, but that no animal which has horns has front teeth in the upper as well as the lower jaw, for Nature gives to the horns material which is withheld from the teeth. ‡

There does not appear to be any animal known to Aristotle which has tusks and horns. The male tufted deer of China and the male muntjacs have scimitar-like tusks in their upper jaws and small antlers; the antlers of the tufted deer are much smaller than those of the muntjacs, but their tusks are longer. Again, the musk deer and Chinese water deer are without antlers, but the males have very long tusks. The carnivores have sharp, interlocking teeth, and many have exceptionally large canine teeth or tusks, but in none of those known to Aristotle do these project like the tusks of the wild boar, and he is probably referring to tusks of this kind, and not to all canines of large size.

In his descriptions of the teeth, chiefly in *H. A.* ii. c. 3, ss. 8–15, and *P. A.* iii. c. i, Aristotle distinguishes the incisors, the canines, the premolars, together with the molars, and the wisdom teeth. The molars and premolars are taken together, either under the name "gomphioi" or under that of "broad teeth," on account of their necks and crowns being broad. He also distinguishes between animals like the lion, leopard, and dog, which are carcharodont, or have sharp, interlocking teeth, and animals like the horse and ox, which have anepallaktous teeth, or teeth with flat crowns. Again, he distinguishes a very large group of amphodont animals, with front teeth in each jaw, from a much smaller group, including the ox, deer, and other ruminants, which are non-amphodont, or have front teeth in the lower jaw only. The way in which he seems to have used these dental characters in classifying animals will be discussed in Chapter xv.

He states, incorrectly, that among some animals, *e.g.*, Man, the sheep, goat, and pig, the males have more teeth

* *Anat. Vertebr.* iii. 1868, pp. 348–9. † *H. A.* ii. c. 3, s. 9.
‡ *P. A.* iii. c. 2, 663*b* and 664*a*.

than the females,* and this statement has often been used against him by critics. He also misunderstood the arrangement of the teeth of camels. He says that they have no front teeth in their upper jaws.† In young camels there are three pairs of incisors in the upper jaw, and in adult camels the pair of incisors next the canines persists.

He also says that all fishes, except the parrot-wrasse, have sharp, interlocking teeth.‡ This statement does not appear to be an interpolation, and yet it is difficult to understand why Aristotle should have made it. The parrot-wrasse has many flat pharyngeal teeth and a parrot-like beak formed by the coalescence of many of its teeth, but Aristotle was well acquainted with the gilt-head, which has some strong, blunt front teeth and many rounded teeth, embedded like peas or beans along the sides of and within its mouth, and he probably knew the eagle ray and the female thornback skate, which have flat teeth.

On the other hand, he makes many interesting statements, substantially or quite correct, about the teeth of many other animals. He says that the elephant has four teeth on each side, for grinding down its food, that it has teeth as soon as it is born, but that its tusks are not visible at birth.§ This is true as regards the teeth on each side except in old elephants, which usually have only two teeth left on each side of the mouth. The elephant usually has, during its whole life, twelve cheek teeth on each side of its mouth. They are developed gradually and move forwards along the jaws at the same rate as the front ones are worn away. The milk tusks of male elephants are not visible at birth, but project beyond the gum between the fifth and seventh months, according to Owen, who also says that the first molars of the Asiatic elephant are in place and in use at three months.‖

Aristotle correctly points out how old and young dogs may be distinguished by means of their teeth, those of young dogs being white and sharp, while those of old dogs are dark and worn.¶ He was also aware of what is called the "mark" in the incisor teeth of horses, for he says that horses differ from other animals in that their teeth become whiter with age, while those of other animals become

* *H. A.* ii. c. 3, s. 13.
† *H. A.* ii. c. 2, s. 6, ii. c. 3, s. 8; *P. A.* iii. c. 14, 674*a*.
‡ *H. A.* ii. c. 9, s. 5; *P. A.* iii. c. 1, 662*a*. § *H. A.* ii. c. 3, s. 15.
‖ *Anat. Vertebr.* iii. 1868, pp. 360 and 362. ¶ *H. A.* ii. c. 3, s. 12.

darker.* Aristotle says that all the teeth of the seal are sharp and interlocking, because it is very closely allied to fishes.† This is true, but the reason given sounds strange; the seal being now classed with the otter and other carnivora. He gives a fair general description of the gastric mill in lobsters and crabs. He says that it is in the part of the stomach which is near the mouth, and that there are three teeth, two lateral ones and one below.‡

The gastric mill is in the hinder part of the large or cardiac portion of the stomach, into which the short, nearly vertical gullet enters. Numerous parts make up the gastric mill, but three are very conspicuous, two lateral and approximately horizontal teeth and a median dorsal one between the posterior ends of the lateral ones.

In *H. A.* iv. c. 4, s. 7, Aristotle says that *Kochlias*, probably *Helix*, has small, sharp, and delicate teeth. This seems like a reference to the lingual teeth, and, if so, the statement shows that he closely examined the structure of the mouth of this animal. He also says that the *Kochloi*, by which some gastropods are meant, have two teeth in addition to a tongue.§ These two teeth may be merely the horny jaws of the gastropods.

Aristotle says that the sea-urchin has five inwardly curved teeth.‖ These teeth with their pyramidal sockets and the numerous pieces of framework supporting the whole are called "Aristotle's lantern," and form a comparatively large structure projecting within the shell of the sea-urchin. Aristotle was the first to direct attention to it, but it was the shell of the sea-urchin divested of its skin which he compared to a lantern.

Aristotle makes the following interesting statements about the shedding of teeth:—"Man and some other animals, *e.g.*, the horse, mule, and ass, shed their teeth. Man sheds his front teeth and no animal sheds its 'molars,' while pigs do not shed any at all. Whether or no dogs shed their teeth is a disputed point; some believe that they do not, others that they shed their canine teeth only, but it has been observed that dogs shed their teeth, like Man, only the shedding escapes notice because the teeth are not shed until new ones, similar to them, have been developed under-

* *H. A.* ii. c. 3, s. 12. † *H. A.* ii. c. 3, s. 9; *P. A.* iv. c. 13, 697*b*.
‡ *H. A.* iv. c. 2, s. 11; *P. A.* iv. c. 5, 679*a*. § *P. A.* iv. c. 5, 678*b*.
‖ *H. A.* iv. c. 5, s. 5; *P. A.* iv. c. 5, 680*a*.

neath. Probably, a similar thing happens in some other animals, which are said to lose their canines only." *

The true molars are not shed, and the Greek word used by Aristotle, *viz.*, *gomphioi*, certainly includes these, but, on account of the ambiguity of his statements, both here and elsewhere, it cannot be asserted that he refers to true molars only. His assertion that pigs do not shed their teeth is incorrect, but is still believed by some. One breeder, in fact, informed me that pigs do not shed their teeth, or, at most, only the canines. Aristotle's interesting statements about the shedding of the teeth of dogs are correct, as far as they go, for the milk teeth are shed and, although there are great variations with respect to time and order of shedding in different dogs, the permanent teeth are usually well-developed before the milk teeth are shed. Before me is the skull of a dog with well-developed upper canines, third upper premolars, and third and fourth lower premolars, all projecting well beyond the bone; the corresponding milk teeth, however, are still in position but in process of being gradually pushed out of their sockets by the permanent teeth.

He states, erroneously, that horns, referring particularly to those of ruminants, are more closely connected with the skin than with the bones, and attempts to explain in this way why certain cattle in Phrygia and other places moved their horns like ears.† This passage gives a wrong impression of the value of his knowledge of these structures. He knew that the horns of ruminants are closely connected with the bones. In *H. A.* iii. c. 9, s. 2, he says that most horns are hollow from their bases and surround an inner bone growing from the head, but are solid at the tip and unbranched, and, in *H. A.* ii. c. 2, s. 11, he says that the hollow parts are produced mainly from the skin, and the hard parts from the bone; in both passages he says that the horns of deer are the only ones which are solid throughout. The supposed close connection between horns and skin caused him to believe that the colours of these correspond, dark horns being found with dark skins or hair, and light horns with light skins or hair, and he believed that the same was true for nails, claws, and hoofs.‡ There are many animals for which these statements are not true,

* *H. A.* ii. c. 3, ss. 11 and 12. † *Ibid.* iii. c. 9, s. 3.
‡ *Ibid.* iii. c. 9, s. 1.

e.g., the gazelle, oryx, and Bubaline Antelope, and, among animals which Aristotle could not have known, the polar bear, and the white cattle of some parts of the Falkland Islands, mentioned by Darwin.*

The deer (*Elaphos*) is the only animal which casts its horns annually, this taking place after it is two years old; its horns are shed about May, and its first horns are straight, like pegs.†

Although Aristotle here uses the word *Elaphos* in the singular, he refers to more than one kind of deer. Except in a few individual cases, deer shed their horns annually, while the horns of oxen, sheep, goats, and such antelopes as were known to him, are not shed. The first horns are peg-like, as Aristotle says, but they are usually shed when the young bucks are not quite two years old. Further, deer usually shed their horns about March.

Aristotle says that all horned animals have four feet, excepting such animals as the horned snakes which, the Egyptians say, are to be found near Thebes.‡ This passage recalls the statement by Herodotus,§ that, near Thebes, there were small harmless snakes, with two horns at the upper parts of their heads. Except that Cerastes is not harmless, this description might well refer to it.

Some peculiar beliefs about snakes with "horns" are to be found in some of the Greek Isles. The official notes, reproduced in *Folk-Lore*, vol. xi. 1900, pp. 120–125, of a trial in the District Court of Larnaca, on October 27th, 1899, state that damages were claimed for the loss of a snake's "horn" lent to the defendant. The plaintiff alleged that he had extracted it from just above the right eye of a snake, and that it was a white, curved, thin body, about three-quarters of an inch long. It was also alleged that it exercised some magic power over the human body, and that water in which the "horn" had been placed was useful in curing snake-bites. Commenting on this case, Mr. W. R. Paton says that the snake's "horn" is known also in Cos,‖ and it may be mentioned that the Nose-horned Viper (*V. ammodytes*) of central and southern Europe has a scaly appendage on its nose.

* *Naturalist's Voyage round the World*, 2nd ed. London, 1890, p. 203.
† *H. A.* ii. c. 2, s. 11, ix. c. 6, s. 2.
‡ *Ibid.* ii. c. 2, s. 11.
§ ii. 74.
‖ *Folk-Lore*, xi. p. 321.

d. *Hair.*—Aristotle gives a long description of the hair of animals, chiefly in *H. A.* iii. c. 10, and, although including many erroneous statements, such description seems to have been, for many centuries, the best.

He says that the thickness, fineness, and length of hairs vary with their positions and the nature of the skin,* that animals with coarse hair become softer-haired, and animals with soft hair become coarser-haired, by good feeding, and that men living in warm localities have harsh hair, while those living in cold localities have soft hair.† He adds that straight hairs are soft, but curly hairs are harsh.‡

Many other conditions, besides the nature of their food, affect the qualities of the hair, but the nature of the food has an important effect, *e.g.*, when the Angora goats of Asia Minor have a variety of good food their hair is finer and in better condition than when their food is coarse. Why Aristotle states that animals with soft hair become coarser-haired by good feeding is not clear. It seems to be, however, an example of his fondness for laying down a proposition and then stating its converse.

When speaking about the hair of men living in warm and in cold localities, he seems to rely on a comparison between the Europeans, with hair fairly straight or moderately curled, and the Negroes, with frizzly hair. It is not clear what he means by softness and harshness, as applied to hair, but he seems to suggest that straightness and curliness respectively are meant. There are important exceptions, however, to his general statements, *e.g.*, the Mongols, whether living in warm countries, like Siam or the Malay Archipelago, or in cold countries, like Siberia, have cylindrical, straight hair, and the degree of frizziness or curliness of the hair of Negroes depends very much on the degree of ellipticity or flatness of the hair in cross section.

Aristotle says that hair becomes grey from the tip, and that, during the course of some complaints, the hair turns grey and falls off but grows again and is of its original colour.§ Hair commonly becomes grey from the roots, sometimes from the tips, and occasionally at intervals along the hairs. Aristotle's statement about the recovery of the hair after illness was probably taken from Hippocrates, and

* *H. A.* iii. c. 10, s. 1.
† *Ibid.* iii. c. 10, s. 2.
‡ *Ibid.*
§ *Ibid.* iii. c. 10, s. 5.

is true particularly of patients suffering from scarlet and other fevers.

Many other statements relating to the hair are made by Aristotle, of which the following seem to be the most interesting: In *H. A.* iii. c. 10, s. 9, he says that the hair grows on dead bodies. Many descriptions of a remarkable growth of hair after death have been given since Aristotle's time, and many people believe that such growth takes place.* However, Dr. W. J. Erasmus Wilson says: "The lengthening of the hairs of the beard, observed in a dead person, is merely the result of the contraction of the skin towards their bulb."†

In a passage which is not clear, Aristotle says that, in animals with spotted fur, the spots first appear in the fur and skin and in the skin of the tongue.‡ I know nothing about such an occurrence of spots on the tongue, but some dogs have dark patches or marks on the palate and other parts within the mouth, and the following record seems to show that there is a relation between the colour of the hair and these marks. Mr. Woodward, a gamekeeper on the Blenheim estate, Woodstock, informs me that about nine years ago a pedigree black retriever, belonging to the Duke of Grafton, had seven pups, six black and one pure white. The black pups had, like their mother, dark or black palates, but the white pup had its palate partly white.

In the case of Dalmatian pups, which are usually white at birth, the spots do not appear until the pups are a few weeks old.

There are several passages, in ancient works, about an influence exercised on the colours of animals by the water drunk by the mothers of these animals or by the animals themselves. Strabo mentions rivers the waters of which had an influence of this kind,§ and so also does Ælian,‖ and there is also the well-known passage in *Genesis*, c. 30, vv. 37–39, which has so often been discussed. Aristotle says that there are waters of this kind in many places, and, by drinking them just before conception, sheep bring forth black lambs, *e.g.*, the so-called Cold River, in the Thracian

* I particularly remember a detailed narrative about an excessive growth of hair after death in connection with a case of exhumation in Worcestershire.

† *Healthy Skin, &c.*, 8th edition, 1876, p. 112.

‡ *H. A.* iii. c. 10, s. 9. § *Geogr.* x. c. 1, s. 14.

‖ *De Nat. Anim.* viii. 21.

Chalcidice. He also says that in Astyra and Antandria are two rivers, of which one makes sheep white and the other makes them black. The river Scammander, he says, seems to make them light brown, and on this account some say that Homer called this river Xanthus.*

The hare is the only animal, Aristotle says, which has hair within its cheeks and on the under sides of its feet.† It is true that the hare has hairs on the insides of its mouth and beneath its feet, but so also have other rodents, like the rabbit and squirrel, and, among animals not known to Aristotle, the polar bear, in particular, has hairs beneath its feet.

e. *Feathers, Scutes, and Scales.*—Aristotle's views on these anhomœomeria are closely connected with his views on the analogy and, it may be said, homology of the parts of animals, and will be more suitably considered from this point of view in Chapter xv.

He mentions the chief parts of a bird's feather, *viz.*, the shaft and barbs, and distinguishes it from the wing of an insect, which appears to be of the nature of a feather, being a skin-like membrane which, because of its dryness, becomes detached from the surface of the body.‡

Aristotle says correctly that many birds change colour with the seasons in such a way that an observer, if inexperienced, is deceived thereby, but he does not correctly explain the occurrence of albino ravens, sparrows, and swallows, for he says that they become white when the cold increases.§ He says also that the crane, which is ash-coloured, darkens with age and is the only bird whose plumage changes with age.‖ This is not correct, for, besides the great changes which take place in the plumage of many birds, from the young to the adult stage, changes in brilliancy or depth of colour may be seen, after successive moults, in many birds. In wild linnets, for instance, the rose-coloured parts are larger and more brilliant in the older birds.

The looseness and thin nature of the barbs of the feathers of the ostrich were known to Aristotle, for he says that they are of the nature of hair and useless for flight.¶

Oviparous quadrupeds, he says, have scutes.** This statement is incomplete, for some, like the frog and water

* *H. A.* iii. c. 10, s. 12.
† *Ibid.* iii. c. 10, s. 13.
‡ *P. A.* iv. c. 6, 682*b*.
§ *H. A.* iii. c. 10, s. 11.
‖ *Ibid.*
¶ *P. A.* iv. c. 13, 697*b*.
** *H. A.* iii. c. 10, s. 1.

newt, have no scutes, and the chamæleon, which Aristotle knew so well, is covered by granules which can be very easily scraped off by means of a knife.

For some time past attempts have been made to ascertain the ages of fishes by an examination of their scales. Aristotle also refers to changes in the nature of the scales of fishes with advancing age, saying that they become harder and thicker, and much harder in fishes which are old and wasted.*

B.—The Heart and Blood-Vessels.

Aristotle's description of the heart and the arrangement of the blood-vessels constitutes his most valuable contribution to anatomical knowledge. Before his time it was generally believed that the origins of the blood-vessels were in the head, and in his *H. A.* iii. c. 2, he gives the arrangements of the blood-vessels according to Syennesis of Cyprus, Diogenes of Apollonia, and Polybus, who scarcely mention the heart. He was the first to explain, in clear language, that the blood-vessels arise from the heart, but he cannot be regarded with certainty as the originator of this discovery, for Plato says that the heart is the bond of union of the blood-vessels, and the fountain of the blood coursing through the limbs.†

Aristotle's reasons for believing that the heart is the origin of the blood-vessels are given in *P. A.* iii. c. 4, where he says that the blood-vessels necessarily have one origin, for, where it is possible, it is better that there should be one and not many. This origin, he says, is in the heart, for the blood-vessels extend from it and not through it, and it occupies a very important or controlling position in the body. Then, after asserting that those are mistaken who believe that the blood-vessels have their origins in the head, he shows that the heart should be in a hot part of the body, and that it is so situated and is well adapted to be the origin and to form part of the arrangement of blood-vessels, for it has thick walls to prevent loss of heat, and is of the nature of a reservoir, the blood passing from it to the vessels, but not returning. All this, he says, is clearly proved by means of dissections and the phenomena of development, for the heart is the first part to be formed and contains blood as soon as it is formed.

* *H. A.* iii. c. 10, s. 10.

† *Timæus*, 70.

According to Aristotle, the heart has three chambers, the largest being on the right side, the smallest on the left side, and the one of intermediate size being between the other two; the two smaller chambers are much smaller than the largest, and, while all the chambers are readily seen in large animals, only two or even one can be seen in smaller animals.*

Apparently, the largest or right chamber is the right ventricle, together with the right auricle, the smallest or left is the left auricle, and the intermediate chamber is the left ventricle. Aristotle's description of the chambers was probably based on dissections of this organ in some mammal or mammals. He does not say what animals he dissected for this purpose, but, for several reasons, more especially because he was acquainted with the existence of a bone in its heart, it is not unlikely that the ox was one of them. If so, it would not be surprising that he considered the right ventricle and right auricle to form one chamber which, as he says, was much larger than either of the other chambers.

When the heart of an ox, freed from its firmly adherent masses of suet, is carefully dissected and placed so as to allow anyone to look down into its auricles and ventricles, the passage from the right auricle to the right ventricle is seen to be much more gradual than the passage from the left auricle to the left ventricle, between which there is a well-marked annular ridge. Then, again, the auriculo-ventricular valves between the right auricle and right ventricle lie very close to the chamber walls, and no well-marked boundary is seen between the right auricle and right ventricle.

It should be mentioned that, instead of the view expressd above, Aubert and Wimmer considered the two auricles to form Aristotle's largest chamber, Frantzius considered this to be the right auricle, and Dr. Ogle the right ventricle.

Aristotle says that there are sinews in the chambers of the heart,† but in *H. A.* iii. c. 5, s. 1, he says that the sinews are in its largest chamber. It is clear that the chordæ tendineæ are meant. These occur, as is well known, in both ventricles.

In *H. A.* i. c. 14, s. 1, the pericardium seems to be referred to, for it is stated that the heart has a thick, fatty membrane, by which it is attached to the great blood-vessel

* *H. A.* i. c. 14, ss. 1 and 2, iii. c. 3, s. 2; *P. A.* iii. c. 4, 666*b*.
† *H. A.* i. c. 14, s. 1; *P. A.* iii. c. 4, 666*b*.

and the aorta. The pericardium of an ox, which was probably one of the animals dissected for the heart, as explained above, is very stout and covered on opposite sides by a large quantity of fat, so that Aristotle's description applies very well to it.

Aristotle's statements about the presence of bones in the hearts of horses and some oxen have been considered already in that part of this Chapter which relates to bones and cartilages.

In his description of the position of the heart, intended to apply to the human heart, he says incorrectly that the heart lies above the lungs, near the bifurcation of the trachea,* and that the parts of the heart near its apex lie on or against the aorta.† In Man, the heart lies just below the bifurcation of the trachea, and not above the lungs, while the apex of the heart is some distance in front of the aorta. One part of Aristotle's description of the position of the human heart, however, is such that some have taken it as a proof that he dissected the human body. This part of his description has been discussed in Chapter viii.

Aristotle says that the heart of a snake is small, kidney-shaped, and situated near its throat.‡ The heart of a snake cannot be considered to be small, nor is it kidney-shaped. In one grass-snake, the heart, enclosed within its pericardium, was an inch and an eighth long and half an inch in diameter, the whole being almost cylindrical with rounded ends. When removed from its pericardium, the heart presented a much more complicated appearance, the bright red ventricle, in the form of a double cone with rounded ends, resting upon and between the dark red auricles. The front part of the heart was about as far forward as the hinder end of the long trachea.

In the animals now called invertebrates, Aristotle did not believe that a heart, properly speaking, could be found. Instead of this, they had a part analogous to a heart, just as they had a fluid which was not blood but analogous to it.

The part, in cephalopods and crustaceans, which he believed to represent the heart of animals with blood, was the part which, he says, was called *mytis*.§ Its position, he says, shows that it corresponds with the heart of animals with blood, and this is proved by the sweetness of its contained fluid, which has the characters of coagulated matter

* *H. A.* i. c. 14, s. 1. † *Ibid.* ‡ *Ibid.* ii. c. 12, s. 12.
§ *P. A.* iv. c. 5, 681*b*; *H. A.* iv. c. 1, s. 11, iv. c. 2, s. 11

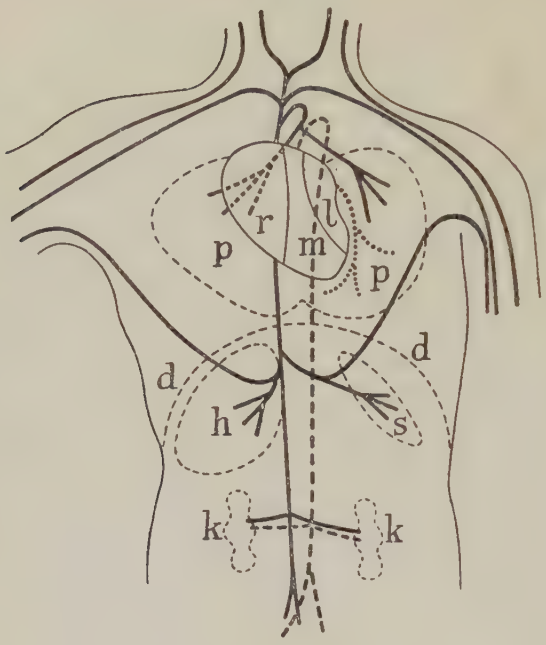
and resembles blood.* The *mytis* was probably the liver or digestive gland. The fluid of this, however, is not always like blood, nor is it sweet. In most dibranchiate cephalopods it is reddish brown, but in the lobster and crayfish it is commonly yellow. In his *Ostrakoderma* and *Entoma* he concluded that the part corresponding with the heart of an animal with blood was in a median position,† but in no case does he appear to have located it.

Aristotle's description of the arrangement of the blood-vessels may now be considered. Reference may be made to Fig. 8, which is intended to illustrate his description. He points out the difficulties of tracing the arrangement by the methods followed by others, who dissected slaughtered animals from which much of the blood had flowed, or who examined the bodies of very emaciated men. It is very probable that he himself dissected animals which, after having been starved, were killed by strangulation.‡

He was aware of some differences (as has already been pointed out in Chapter ix.) between what are now called arteries and veins, but he had no knowledge of a circulation of the blood. According to him, the blood flowed outwards from the heart and did not return. In the following description, therefore, the phrase "blood-vessel" will be used wherever possible; it would be misleading to use the words "artery" and "vein." Except where otherwise stated, in the following description of the arrangement of the blood-vessels, according to Aristotle, the passages relied on are from his *H. A.* iii. cc. 3 and 4 (Schneider's text). Aristotle says that two blood-vessels arise from the heart, the smaller one, which some call the aorta, lying a little to the left, and the larger one, called the great blood-vessel, lying a little to the right of the spinal column and nearer to the ventral wall than the aorta. The heart is, as it were, a part of these blood-vessels, especially the great blood-vessel, for the parts of this extend above and below the heart, which is between them. The great blood-vessel, he says, is connected with the upper part of the largest chamber, on the right side, then its course is directed backwards right through the chamber, as if this were a part of the blood-vessel acting as a reservoir. The aorta, on the other hand, arises from the middle chamber, but not in the

* *P. A.* iv. c. 5, 681*b*. † *Ibid.* iv. c. 5, 681*b* and 682*a*.
‡ *H. A.* iii. c. 3, s. 1.

FIG. 8.



HEART AND BLOOD VESSELS ACCORDING TO ARISTOTLE.

r, m, l. Chambers of the heart.
p. Lungs.
d. Diaphragm.
h. Liver.
s. Spleen.
k. Kidneys.
——— Great blood vessel and its branches.
------ Aorta and its branches.
..... Blood vessels from left chamber.

same way as the great blood-vessel, for it communicates with the heart by a much narrower passage, and merely extends from it, whereas the great blood-vessel passes through the heart.

Aristotle's description of the relative positions of the great blood-vessel and the aorta, or rather the parts of these which pass downwards along the spinal column, is not quite correct, for, although most of the great blood-vessel is nearer the ventral wall than the aorta, its lower part is not. Again, in its downward course the aorta tends to the right, so that its lower part may be more correctly said to lie in front of the spinal column. It is evident, from his own statement, that Aristotle was not the first to give the name *aorta* to the blood-vessel which, since his time, has been almost always called the aorta. In one of the Hippocratic treatises,* not written by Hippocrates but probably by a contemporary, the name *aortæ* is given to the bronchial tubes. Aristotle does not always use the phrase "great blood-vessel" in the same sense; usually it refers to some part or parts of the venæ cavæ and pulmonary artery, but, in any particular passage, its meaning must be ascertained from the context.

The largest chamber, on the right side, to which Aristotle says that the great blood-vessel is connected, is the right ventricle, together with the right auricle, as explained already, and the middle chamber, from which the aorta is said to arise, is the left ventricle. Aristotle's statement about the relative sizes of the roots of the aorta and the great blood-vessel, whether this be taken to be one of the venæ cavæ or the pulmonary artery, is incorrect. He probably never saw these vessels in Man, in whom there is but a small difference in size between the root of the aorta and the root of the pulmonary artery. Again, to take an animal the heart of which he probably dissected, the root of the aorta of a three-year-old ox was a little larger than the root of the pulmonary artery and much larger than the root of either vena cava.

Aristotle describes the largest chamber as if it were a reservoir-like part of the great blood-vessel, and it is clear that he considered this chamber, or at least that part of it now called the right auricle, to be a dilatation of the great blood-vessel.

* *On Places in Man*, c. 14.

Aristotle proceeds to describe the various blood-vessels which pass from the parts of the great blood-vessel above the heart. He says that a part of the great blood-vessel passes upwards as an undivided blood-vessel of large size, and that two vessels extend from it. One of these goes towards the lungs and divides into two vessels, one for each tracheal tube; these two vessels break up into smaller and smaller vessels which ramify through the substance of the lungs, so that the whole of these seems to be full of blood. The other vessel, which extends from the upper part of the great blood-vessel, passes to the spinal column and the last cervical vertebra.

The great blood-vessel, referred to in the above statements, is clearly the pulmonary artery, and Aristotle's description of the arrangement of the blood-vessels passing from it to the lungs will be more conveniently discussed in Chapter xi. His assertion that a blood-vessel extends from the great blood-vessel to the spinal column and the last cervical vertebra is by no means easy to understand. The pulmonary artery has no branch of this kind. His further description of the great blood-vessel and its branches almost suggests that he was referring to the large azygos vein, but it does not seem to be possible to identify the blood-vessel which he so strangely connects with the pulmonary artery. His description of the two blood-vessels passing from the upper part of the great blood-vessel is an example of passages in which a fairly good description is followed by an apparently inexplicable statement. Such passages often occur in his description of the arrangement of the blood-vessels, and, in some cases, it is almost futile to attempt to do more than refer to them.

Aristotle proceeds to say that, from the "whole" (which should be the *vena cava superior*), blood-vessels pass to the sides and collar bones and thence to the arms in men, to the forelegs in quadrupeds, to the wings in birds, and to the pectoral fins in fishes. The parts of these blood-vessels near where the branching takes place he calls the *jugulars*. He also says that blood-vessels pass from the great blood-vessel to the neck and along the trachea, and that, when these blood-vessels are held on the outside, men sometimes fall down insensible, with eyes closed, but without being choked. These blood-vessels, he says, extend as far as the ears, where they branch off into four vessels, one of which turns back and passes through the neck and shoulder on its way

to the arm, hand, and fingers, while another extends to the membranes surrounding the brain. Of the remaining branches of the great blood-vessel, some pass completely round the head, and others end in very delicate vessels in the sensory organs and the teeth.

It is clear, from the first part of this description, that Aristotle saw what are now called the subclavian veins and some of their tributaries, and that what he calls the *jugulars* were probably the innominate veins. The blood-vessels, the holding of which caused men sometimes to fall down insensible, should be the internal jugulars, since Aristotle is discussing branches of the great blood-vessel, but he may be referring to the carotid arteries. It may be mentioned that compression of the carotids to produce stupor during surgical operations was practised by the Assyrians.* The part of Aristotle's description of the blood-vessels extending as far as the ears is apparently meant to refer to the internal jugular veins and their tributaries, but several parts of the description are incorrect, *e.g.*, these veins have many more than four tributaries, and the branching takes place at many different places and not merely in the vicinity of the ears. Again, the vessel which is said to pass back through the neck might be one of the external jugular veins.

Aristotle's account of the blood-vessels connected with the brain will be considered when dealing with the brain and spinal cord.

The part of the great blood-vessel below the heart will now be considered. Aristotle says that this passes down through the diaphragm, but he adds the erroneous statement that it is united to both the aorta and the spinal column by loose, membranous connections. A short, thick blood-vessel passes from it to the liver and breaks up therein. There are also, he says, two branches of this short, thick blood-vessel, one ending in the diaphragm and adjacent parts, and the other passing upwards and entering the right arm. Therefore, he explains, when surgeons cut this blood-vessel, some pains about the liver are relieved. From the left side of the great blood-vessel, a short, thick blood-vessel passes to the spleen, and another blood-vessel passes upward and into the left arm. Other blood-vessels extend from the great blood-vessel, one to the omentum, another to the so-called pancreas, and many blood-vessels through the

* *Manual of Pharmacology*, W. E. Dixon, 2nd edition, 1908, p. 51.

mesentery, but these all end in one great blood-vessel extending along the intestine and stomach and as far as the œsophagus.

This practically completes Aristotle's description of the great blood-vessel and its connections. The way in which he describes the downward extension of the great blood-vessel suggests that he knew that what is now called the *vena cava inferior* passed somewhat centrally through the diaphragm. In his description of the branches of the blood-vessel passing to the liver, Aristotle is wrong; the blood-vessels from the right part of the diaphragm pass to the *vena cava inferior*, and those from the left part enter the suprarenal vein. His statements, that another branch passes upwards and enters the right arm, and that a blood-vessel passes from the left side of the great blood-vessel to the left arm, are of more than ordinary interest. He was evidently not free from the influence of the ancient belief in the existence of distinct right and left systems of blood-vessels. Statements made in accordance with this belief vitiated the descriptions of all ancient anatomists who dealt with the arrangement of the blood-vessels, and used to exercise a bad effect on surgical practice. Diogenes of Apollonia, one of the best anatomists who lived before Aristotle, described some of the blood-vessels of the right arm and shoulder under the name "hepatitis," and some of the blood-vessels of the left arm and shoulder under the name "splenitis," * and said that, for some complaints, surgeons practised bleeding from them.† The Ancients believed, in fact, that an organ, such as the liver or spleen, was connected by a blood-vessel with a distant part of the body, such as one of the arms, and surgeons tried to relieve pains, believed to be caused by such an organ, by bleeding from the aforesaid blood-vessel. Dr. Lauth says that the erroneous opinion, which even Aristotle entertained, that a blood-vessel connected the liver and the right arm, and that another connected the spleen and the left arm, long had a bad effect on surgical practice.‡

The Chinese, who appear to have formed their ideas about human anatomy without the aid of the dissecting-knife, believe that there are some organs to each of which a blood-vessel proceeds, such vessel having a "pulse" which

* *H. A.* iii. c. 2, s. 4. † *Ibid.* iii. c. 2, s. 6.
‡ *Hist. de l'Anatomie*, Strasbourg, 1815, p. 77.

is of great value in diagnosis. An account of this subject may be read in a paper by Dr. J. Dudgeon in the *Journal of the Peking Oriental Society*, vol. iii. No. 4 (1895), pp. 555–565. He gives, by way of example, the "pulse" of the large intestines, and says that the blood flowing to these rises at the tips of the thumb and index finger, flows up the back of the arm to the head, then down the face to the lungs, and thence to the intestines, that two blood-vessels are also given off to the ears and nose, and that deafness, ringing in the ears, and pains behind the ears and in the arms arise from the large intestines. Nothing is said about blood-letting, but the general similarity between the views of the ancient Greeks and the Chinese, as expressed above, shows that these peoples, so far removed both in space and time, have entertained similar ideas about the blood system.

Returning to Aristotle's description of the blood-vessels connected with the great blood-vessel, it is clear that, as might be expected, he misunderstood what is now known as the portal system of blood-vessels, some of which he describes as if they passed directly into the great blood-vessel. The veins from the spleen, pancreas, omentum, and mesentery are not tributaries of the *vena cava inferior*, but unite to form the portal vein which enters and breaks up in the liver.

Most of the rest of Aristotle's description of the blood-vessels relates to the aorta and its branches. He states, but incorrectly, that both the aorta and great blood-vessel are unbranched as far as the kidneys, and then he correctly follows the courses of these vessels, in so far as he says that they cling more closely to the spinal column and that each divides into two, just like the Greek Λ, but that the great blood-vessel lies farther back than the aorta.

He says that blood-vessels pass from the aorta to the mesentery, and that no blood-vessel passes from the aorta to the liver and spleen, but blood-vessels extend from both the aorta and the great blood-vessel to the hips. Blood-vessels, he says, extend to the kidneys from the aorta and the great blood-vessel; they do not pass to the hollow parts [*pelves*] of the kidneys, but are abundantly supplied to their substance. From the aorta two other strong, unbranched ducts (*poroi*) lead to the bladder, and others, having no connection with the great blood-vessel, from the hollow parts of the kidneys. Then follows a description, by no means clear, of tubular, sinewy blood-vessels passing from the kidneys along the

spinal column to the hips, and then to the bladder and generative organs.

It is clear from these descriptions that Aristotle was acquainted with the mesenteric arteries, but that he did not know that arteries are given off almost directly from the aorta to the liver and spleen, these arteries being branches of the very short cœliac artery, which leaves the abdominal aorta just below the diaphragm. He very clearly refers to the ureters, but it is not clear what are the two strong, unbranched ducts (*poroi*) leading from the aorta to the bladder. The use of the word *poroi* instead of *phlebes* does not cause the difficulty, for Aristotle often uses that word to denote blood-vessels; the difficulty is that there do not seem to be blood-vessels corresponding with those mentioned. They may be the spermatic arteries, or the corresponding ovarian arteries, which are long, unbranched vessels extending in the direction of, but not to, the bladder. They can scarcely be two of the vesical arteries, which are given off from the internal iliac arteries and are very much branched.

No blood-vessel, Aristotle says, passes from the great blood-vessel to the uterus, but many closely crowded blood-vessels extend to it from the aorta. He next says that, after their bifurcation, blood-vessels extend from the aorta and great blood-vessel to the groins, legs, feet, and toes.

His statement that no blood-vessel extends from the great blood-vessel to the uterus is substantially correct, for many of the uterine veins lead to the internal iliac veins; some of them, however, communicate with the ovarian veins which lead to the *vena cava inferior*. His statement about the vessels extending to the uterus from the aorta needs some qualification. The uterus is supplied with blood partly by the uterine arteries from the internal iliac arteries, and partly by the ovarian arteries which branch off from the aorta and communicate with branches of the uterine arteries.

Aristotle says incorrectly that, as regards the largest blood-vessels and their origins, the arrangement is the same in all animals with blood. In small animals, he says, the blood-vessels, except the great blood-vessel, are not conspicuous, for some blood-vessels are confusedly arranged, just like channels in a large quantity of mud, and some animals have merely a few "fibres" instead of blood-vessels. In a dissected animal, especially one killed by strangulation

or by chloroforming, the pulmonary arteries and the venæ cavæ are distended, and dark or nearly black so as to be easily seen. Aristotle says correctly that the great blood-vessel is conspicuous even in very small animals.

Here, near the end of a description having serious defects, yet far surpassing in excellence the corresponding descriptions of his predecessors, we see that Aristotle tried, but without success, to make out the nature of the small ramifications of the blood-vessels. More than this, it is clear from other passages in his works that he tried to investigate the phenomena of the ultimate destination of the blood passing through the very small blood-vessels. His views are fairly expressed in a series of passages in his *P. A.* iii. c. 5, 668, which are too long to be given in full. In these passages he says that, just as in the conveyance of water by irrigating channels or ditches the largest channels persist but the smallest disappear beneath the mud, so it is with the blood-vessels, for the largest persist while the smallest functionally become flesh, although they are none the less capable of acting as blood-vessels. When flesh is cut, he proceeds to say, blood flows from it, although no blood-vessels may be seen in the flesh, because of their being choked up. The blood-vessels, he says, divide and become smaller and smaller, until their passages are too small to allow the blood to flow through them, but they still allow the passage of a more liquid substance, *viz.*, sweat. Finally, he says that the blood in the very small blood-vessels gives up some of its material in the form of sweat or vapour, or, as stated in *P. A.* iii. c. 8, 671*a*, is diverted into feathers, scales, or the like, while the remaining parts are transformed into flesh.

In this way he explains how the blood can flow away from the heart and never return. Although he was aware of some differences between the aorta and the great blood-vessel and their ramifications, he had no conception of a return of blood to the heart, nor of the existence of networks of capillaries through which the blood passed before entering the veins. Having imperfect means of investigation and an inadequate idea of the difficulties to be overcome, it is not surprising that he failed in his attempts to explain the ultimate distribution and functions of the blood, but he did more than any other anatomist who lived before the times of Vesalius and Servetus to prepare a way for a satisfactory explanation of the phenomena of the circulation of the blood.

CHAPTER XI.

ARISTOTLE'S ANHOMŒOMERIA AND THEIR FUNCTIONS (*continued*).

C.—Lungs, Gills, and the like.

Many interesting statements are made by Aristotle about the lungs, gills, and the structures which, according to him, take their place in some animals, but his views on their functions were quite different from those accepted to-day. He believed that these organs mainly served to cool the animals to which they belonged. Not only did he not understand the respiratory function of the water passing through the gill chambers,* but he also held that air could not exist in the water.† He says that insects and other animals belonging to his *Entoma* cannot respire,‡ and, in support of this statement, he says that many of the *Entoma* live when divided into two or more parts, and that flies and bees swim about for a long time in water, unless this is very cold or hot.§ For him, respiration had a limited meaning. Unlike Diogenes, Anaxagoras, Democritus, and many other philosophers, he denied that animals without lungs could respire,‖ and, even in animals with lungs, the air taken in and expelled served merely to cool the blood and the heart, which was the chief centre of heat.¶

Such were his views on the functions of lungs, gills, and the like. Further information about these views will be given in the following discussion of his statements about the structure and arrangement of these organs.

Aristotle says that the lung is usually double, but this is not so evident in viviparous animals, and least of all in Man, and that the human lung is not divided into many lobes, as in some animals, nor is it smooth, but irregular.** In oviparous animals, he says, such as birds and oviparous

* *De Respir.* c. 16.
† *Ibid.* c. 2.
‡ *H. A.* i. c. 1, s. 7.
§ *De Respir.* cc. 3 and 9.
‖ *Ibid.* cc. 1 and 2.
¶ *Ibid.* cc. 16 and 21.
** *H. A.* i. c. 13, s. 6.

quadrupeds, the parts of the lung are separated so much that there seem to be two lungs, connected to a single trachea.*

The fact that the lungs communicate with a single trachea caused Aristotle to speak of the lung, not the lungs, of an animal. This mode of describing the lungs is somewhat similar to his method of describing the double gills of some fishes. His description of the external appearance of the human lungs is not satisfactory. The lungs, in Man, are distinctly separate, and the left lung has two and the right lung three lobes.

He says that the hollow parts of the lung comprise cartilaginous passages in the lung substance, such passages contracting to a point, and from them are perforations through all parts of the lung, and these perforations, by branching, become smaller and smaller.†

This description reads accurately enough when compared with the appearance presented by the branches, within the lungs, of the bronchial passages of an ox or sheep, such branches having been cut longitudinally. The word used in the Greek text to denote the branches is *diaphyseis*, which indicates that they are in the substance of the lungs.

In a series of very important passages, Aristotle says that blood-vessels extend from the heart to the lung and branch in the same way as the trachea, closely following its branches throughout the whole lung. Between the branches of the blood-vessels and those of the trachea, he says, there is no common duct, but by reason of their contiguity the blood-vessels receive air and transmit it to the heart, for one of the blood-vessels leads to the left and the other to the right chamber of the heart. He also says that the disposition of the blood-vessels and ramifications of the bronchial tubes is such that no part of the lung can be detected in which an air passage exists without a small blood-vessel.‡

These passages are interesting because they foreshadow a conception of that interchange of gases, between the blood and the air within the lungs, which is an important effect of the process of respiration. Aristotle believed that air passed, in some way, from the small air passages into the closely adjacent branches of the pulmonary blood-vessels, and that these branches transmitted it to the heart. He

* *H. A.* i. c. 13, s. 7. † *Ibid.* i. c. 13, s. 7.
‡ *Ibid.* i. c. 14, s. 3, iii. c. 3, s. 4.

does not explain how the air passes into the blood-vessels, but says that there are no ducts or vessels connecting the air passages and the blood-vessels. It may be that he believed in the existence of minute apertures in the passages and vessels, which allowed air to pass, but were too small to allow blood to pass through them.

His views on this part of the subject of respiration are difficult to understand. Some writers have concluded that Aristotle held that some of the blood-vessels contained air and not blood. It may be confidently asserted that his genuine works prove conclusively that, according to him, blood flowed through what are now called arteries as well as through those now called veins. When referring to both kinds of blood-vessels, he often speaks of the blood in them. The erroneous view that some of the vessels contained air rather than blood was held, not by Aristotle, but by many of his followers, as will be shown later.

Few physiologists, according to Aristotle, had discussed the subject of respiration before his time.* Among others, he mentions Empedocles, who believed that some of the blood-vessels were only partially filled with blood, and communicated with the external air through passages so small that they allowed air to pass, but not blood, and Aristotle states that Empedocles tried to explain the phenomena of respiration by asserting that the blood moved to and fro in these blood-vessels, causing the external air to be alternately drawn into and expelled from them through the very small passages and through the mouth and nostrils.† The very small passages, too small to allow blood but large enough to allow air to pass through, were referred to by writers on the blood-vessels and respiration for many centuries after the time of Empedocles. It has already been suggested that Aristotle believed in their existence in the walls of the air passages and blood-vessels in the lungs, and, in *H. A.* iii. c. 3, s. 3, he says that all the chambers of the heart communicate by passages with the lung, but this is not evident, except in one chamber, because of the smallness of the passages. This does not prove that he believed in the existence of passages as small as those mentioned by Empedocles, but it is the clearest statement I can find on this subject.

After Aristotle's time, Erasistratus and many others held that some of the blood-vessels, especially the arteries, con-

* *De Respir.* c. i. † *Ibid.* c. 7.

tained air rather than blood. It was against this belief that Galen directed his attacks, when he contended that the arteries were filled with blood, However, according to Sir M. Foster, the Galenic philosophy set forth that, when the heart expands, it draws air from the lungs, through what are now known as the pulmonary veins, into the left ventricle, and this air mixes there with blood which has passed through invisible pores in the septum between the ventricles.* This shows how lasting was Empedocles' conception of the minute passages.

Aristotle says that, in oviparous animals, such as birds, and oviparous qaadrupeds, the parts of the lungs are separated so much from each other that there appear to be two distinct lungs,† and that, in snakes, there is a single lung divided by a long " fibrous " tube.‡

Except that the trachea is only partly fibrous, this is true of the lungs of the viper and grass-snake, which were those best known to Aristotle. Some snakes, like the boa and python, have two functional lungs, unequally developed.

He says that the lungs of oviparous animals, *e.g.*, lizards, tortoises, and birds, are small and dry but capable of great expansion, when inflated.§ This assertion is qualified by a passage in *P. A.* iii. c. 8, 671*a*, where he says that the marine tortoises have flesh-like lungs containing blood, like the lungs of oxen, and that the lungs of land tortoises are larger proportionally than those of other oviparous quadrupeds. Compared with those of many oviparous animals, the lungs of marine and also land tortoises are large and fleshy, but they are not nearly as fleshy as those of an ox. Aristotle's statement about the lungs of birds is inaccurate, for the lungs of birds are rather large and contain much blood. They are hidden to a large extent in recesses on each side of the backbone, and it is probable that he never removed them in order to examine them.

By means of the currents of water bathing the gills, Aristotle believed that fishes were cooled, but this was not the only function of the gills, for he says that they serve also as organs of smell.‖

His descriptions of the gills of fishes are often difficult to understand. He says correctly that the gills are either single or double, and that the numbers of gills are equal on

* *Lect. on the Hist. of Physiology*, 1901, pp. 12 and 13.
† *H. A.* i. c. 13, s. 7.
‡ *Ibid.* ii. c. 12, s. 12.
§ *P. A.* iii. c. 6, 669*a*.
‖ *Ibid.* ii. c. 16, 659*b*.

both sides of the head.* In a comparatively few fishes, the last gills are single, but he states incorrectly that they are single in all or most fishes.† Again, many gills which are known to be double are said by him to be single. This may be explained, in some cases, on the assumption that he included among single gills those which, like the gills of the eel and the sturgeon, have two sets of leaflets joined together for a rather large part of their length. He does not appear to have known anything of the half-gills or pseudobranchs in some bony and cartilaginous fishes.

In *H. A.* ii. c. 9, s. 4, Aristotle mentions many fishes and gives the numbers of gills for each. In the following table, the gills of some of these fishes are compared with those of the fishes which seem to furnish the best identification of them:—

Aristotle's Fishes	Gills on each side		Modern names	Gills on each side	
	Double	Single		Double	Single
Enchelus	—	Four	Eel	Four	—
Glanis	Three	One	Parasilurus	Four	—
Gongros	One	One	Conger	Four	—
Kyprinos	Three	One	Carp	Four	—
Muraina	—	Four	Muræna	Four	—
Perke	Three	One	Perch	Four	—
Skaros	One	One	Parrot-Wrasse	Three	One
Xiphias	Eight	—	Sword-fish	Four	—

In addition to other peculiarities of structure, the gill-processes of each pair are free in the sword-fish, so that there seem to be eight gills. Aristotle evidently knew of this peculiarity.

Aristotle says that the flat, cartilaginous fishes, such as the torpedo and ray, have their gills below, but the long ones, such as the dogfishes, have lateral gills, and that the fishing-frog has lateral gills, but these have skin-like opercula and not spiny ones, like fishes which are not cartilaginous.‡

The Angel-fish (*Rhina squatina*), which was known to

* *H. A.* ii. c. 9, s. 4. † *H. A.* ii. c. 9, s. 4; *P. A.* iv. c. 13, 696*b*.
‡ *H. A.* ii. c. 9, s. 3.

Aristotle, is a flat cartilaginous fish but has lateral gill-slits. His statement about the gill covers of the fishing-frog is substantially correct. No opercula, such as those of the bass or perch, are present. The respiratory water currents, on each side, flow to the exterior through a large bag-like chamber, bounded exteriorly by a skin-like flap and communicating with the external water through a round hole just behind the base of the pectoral fin. Six very long branchiostegal rays support the skin-like flap.

Aristotle noticed the existence of gills in some of the invertebrates, *e.g.*, he says that gill-like organs, rough, numerous, and constantly moving, are present in lobsters and cray-fishes,* and it is probable that the hair-like organs in the bodies of certain cephalopods,† and the hair-like organs in some molluscs,‡ are intended to be gills.

In his *Entoma*, Aristotle considered the *hypozoma*, *i.e.*, the part of the body separating the thorax from the abdomen, to be the equivalent of lungs or gills, and to be an organ of smell.§

D.—Liver, Spleen, and Pancreas.

Aristotle's statements about the functions of the liver and spleen are few and of very little value; about the functions of the pancreas he says nothing. The liver, he says, cannot be the most important organ of the body nor the origin of the blood, for it does not occupy an important or controlling position, and, further, it is counterbalanced, as it were, by another organ, *viz.*, the spleen.‖ He was disposed to regard the liver and the spleen as resembling each other in character and constituting a double organ.¶ Both the liver and the spleen, he says, assist in the digestion of food, by means of their heat, and the spleen withdraws superfluous matters from the stomach and entirely digests them.** Plato's views on the function of the spleen bear some resemblance to Aristotle's, for he says that the spleen, acting like an absorbent body, serves to receive impurities from the liver.†† The liver, Aristotle says, assists in keeping the body in a healthy condition, for this depends very much

* *H. A.* iv. c. 2, ss. 7 and 10; *P. A.* iv. c. 8, 684*a*.
† *H. A.* iv. c. 1, s. 12. ‡ *Ibid.* iv. c. 4, s. 12.
§ *P. A.* ii. c. 16, 659*b*. ‖ *Ibid.* iii. c. 4, 666*a*.
¶ *Ibid.* iii. c. 7, 669*b*. ** *Ibid.* iii. c. 7, 670*a* and *b*.
†† *Timæus*, 72.

on the blood, and the liver contains more blood than any internal organ, except the heart.*

He discusses the purpose served by the bile, and concludes that its formation results in a purification of the blood, but that it is itself a residual substance having no further use.† His views on the bile were very different, therefore, from modern views, according to which the bile facilitates the absorption of food, especially fats and carbohydrates, and stimulates the peristaltic movements of the intestines.

Aristotle makes a few interesting statements about the position, form, size, and colour of the liver in various animals. That of Man, he correctly says, is on the right side of the body, and he adds that it is rounded like that of an ox.‡ He gives an approximately correct estimate of the relative sizes of the liver of an elephant and an ox, saying that the former is four times larger than the latter.§ The average weight of the liver of English oxen is about sixteen pounds, and that of the liver of Asiatic elephants is about fifty-three pounds.‖ He says very little about the liver in birds. In snakes, he says, the liver is long and single,¶ and, in fishes, some have a liver without lobes and dogfishes have a liver with two lobes which are quite free from each other.** In snakes, the liver is single and elongated, *e.g.*, in a grass-snake of average size I found that the single liver was five inches long. With respect to fishes, there are some, *e.g.*, the Lophobranchs, in which the liver is unilobed, but most usually it is bilobed or, very occasionally, has more than two lobes. The lobes of the liver of the dogfish are connected anteriorly by a short septum, and it is only in a few fishes that they are separate, *e.g.*, they are said to be quite separate in the hag-fish.

The liver, he says, is red in viviparous quadrupeds and birds, light yellow in most oviparous quadrupeds and in fishes, and of a dirty tint in the frog, toad, and the like.†† The colours are more varied than the above statements suggest, *e.g.*, the liver of the grass-snake is of a bright, chocolate colour, that of the sea-lamprey is green, of the dogfish, brownish-yellow, and of the frog, brown.

* *P. A.* iii. c. 12, 673*b*.
† *Ibid.* iv. c. 2, 677*a*.
‡ *H. A.* i. c. 14, ss. 5 and 6.
§ *Ibid.* ii. c. 12, s. 8.
‖ Vet.-Capt. Evans' *Treatise on Elephants*, 1901, Rangoon, p. 67.
¶ *H. A.* ii. c. 12, s. 12.
** *Ibid.* ii. c. 12, s. 3.
†† *P. A.* iii. c. 12, 673*b*.

There are few parts of the animal body to which Aristotle paid more attention than the gall-bladder. When he describes this part, he oftens uses the word *chole*, which properly signifies "bile," to denote the gall-bladder itself.

He says that deer, horses, mules, asses, seals, and some mice and men are without a gall-bladder, but that the so-called Achainian deer seem to have gall in their tails, but this, though like gall in colour, is not liquid like gall, but resembles the inner parts of the spleen.*

Horses, mules, asses, almost all kinds of deer, and some mice, *e.g.*, the long-tailed field mouse, and occasionally men, have not a gall-bladder, but the common seal and all other seals, apparently, have a conspicuous gall-bladder.

Aristotle's statements about the presence of a gall-like substance in the tails of certain deer are not satisfactory. In his note on *H. A.* ii. c. 11, s. 5, Schneider says:—"Even to-day, several huntsmen assert this. It is certain that the inner part of the tail has a greenish colour and a bitter taste. Hence, of course, the opinion seems to have arisen about the presence of bile in the tail." I cannot obtain any confirmation of this. On the contrary, Mr. Woodward, a gamekeeper near Woodstock, who has dressed many deer, says that he has never seen such greenish colour in or about their tails.

Relying on observations on animals slaughtered for sacrifice, Aristotle says that some have not a gall-bladder, *e.g.*, the sheep about Chalcis, in Eubœa, but that all those in Naxos have remarkably large gall-bladders.† He states correctly that the liver of the elephant is without a gall-bladder, but, when cut near the part corresponding with that where the gall-bladder is attached in some animals, a bile-like liquid flows from the cut part, and that the dolphin also is without a gall-bladder.‡

The elephant has a long bile-duct of large diameter opening, according to Owen, into a bile pouch between the coats of the duodenum.

Aristotle attempted, in *H. A.* ii. c. 11, ss. 7 and 8, ii. c. 12, s. 12, and *P. A.* iv. c. 2, 676*b*, to indicate the position of the gall-bladder in many birds and fishes and in a snake. It is clear from these passages that he was well acquainted with the

* *H. A.* ii. c. 11, s. 5; *P. A.* iv. c. 2, 676*b*.
† *H. A.* i. c. 14, s. 6; *P. A.* iv c. 2, 677*a*.
‡ *H. A.* ii. c. 11, s. 7.

zigzag arrangement of the gall-bladder of the pelamid, and the exceptionally large size of the gall-bladder of the star gazer. To what extent he was correct in defining the positions of the gall-bladder in the snake and some of the birds and fishes, referred to above, will be seen from the table below.

Aristotle's Animals	Position of the gall-bladder	Modern names	Position of the gall-bladder
Chelidon	Near the intestines	Swallow	Bile ducts only (two specimens dissected)
Ortyx	,, ,,	Quail	Close below right part of liver
Peristera	,, ,,	Pigeon	Bile ducts only
Strouthos	,, ,,	Sparrow	Bile ducts only (five specimens dissected)
Hydros	On the liver or towards intestines.	Grass Snake	About half an inch behind the liver
Amia	On the intestines	Pelamid	Lies along the intestines
Batrachos	Near the intestines	Fishing-frog	Suspended about thre inches below liver (Owen)
Gongros	,, ,,	Conger	Suspended from liver
Muraina	,, ,,	Muræna	Suspended at some distance from liver (Owen)
Xiphias	,, ,,	Sword Fish	Suspended at some distance from liver
Enchelus	Near the liver	Eel	Close below liver
Glanis	,, ,,	Parasilurus	Close below liver (Agassiz)
Kallionymos	On the liver	Star Gazer	Suspended from liver (Cuvier and Valenciennes)

The spleen, Aristotle says, is on the left side of the body and, in Man, is long and narrow, like that of the pig or dog,* in the elephant it is rather less than four times larger than that of the ox,† in ruminants it is of somewhat rounded form, and in the horse, mule, and ass it is broad in one part and narrow in another.‡

The human spleen is somewhat tetrahedral in form and is not like the elongated spleen of the pig. The spleen varies much in weight, even in mammals of the same species, but Aristotle's estimate of the size of the spleen in the elephant is too high. The average weight of the spleen in English

* *H. A.* i. c. 14, ss. 5 and 6; *P. A.* iii. c. 12, 674*a*.
† *H. A.* ii. c. 12, s. 8. ‡ *P. A.* iii. c. 12, 674*a*.

oxen is about two and a quarter pounds, and that of Asiatic elephants is about seven pounds, acccording to Vet.-Capt. G. H. Evans.*

Aristotle says that most animals with blood have a spleen, but, in many oviparous animals, it is so small that it nearly escapes notice, especially in most birds, such as the hawk, owl, kite, and pigeon, that the *Ægocephalos* has no spleen at all, and that it is quite small in oviparous quadrupeds, such as the tortoise, lizard, crocodile, toad, and frog.† He also says that the chamæleon does not appear to have a spleen.‡

His statements about the absence of the spleen are not satisfactory, for Rolleston says:—"A spleen is found in all vertebrata in connection with the mesogastrium."§ The chamæleon has a small spleen; in one of large size I found it was 0·11 inch long. The *Ægocephalos*, which was a bird, would have a spleen; this bird has not been satisfactorily identified, but different writers have attempted to identify it with one of the following:—godwit, long-eared owl, Scops' owl, goatsucker, and snipe.

Generally speaking, the spleen is relatively much larger in mammals than in birds, reptiles, and batrachians, yet it was oval and 0·68 inch long in one tawny owl, egg-shaped and 0·6 inch long in a small specimen of the Grecian tortoise, and it is said to be large in the crocodile. In some of the other animals mentioned by Aristotle it is certainly small, *e.g.*, it was 0·2 inch long in one wall lizard, and 0·18 inch long in a frog.

Aristotle was aware that the spleen was particularly liable to be diseased.‖

He gives but little information about the pancreas. He merely says that a blood-vessel extends from the great blood-vessel to the so-called pancreas.¶ This suggests that the pancreas was not generally known in his time, and Aristotle seems to be the first to mention it. I cannot find any reference to it in the works of Hippocrates, and the information given by the ancient writers, Rufus Ephesius, Galen, and others who lived after Aristotle's time, is quite unimportant.

* *Treatise on Elephants*, Rangoon, 1901, p. 67.
† *H. A.* ii. c. 11, s 4. ‡ *Ibid.* ii. c. 7, s. 5.
§ *Forms of Animal Life*, 2nd edition, 1888, p. 353.
‖ *P. A.* iii. c. 4, 667*b*. ¶ *H. A.* iii. c. 4, s. 2.

E.—The Alimentary Canal and its closely connected parts.

Many parts of Aristotle's statements about the alimentary canal, omentum, mesentery, and diaphragm are of small value, but there are some parts which describe very well a few important anatomical details. He gives, *e.g.*, good descriptions of the stomach of a ruminant, the pyloric cæca of fishes, and the intestinal cæca of birds, the stomach of the mullet, the gizzard, proventriculus, and crop of a few birds, and the stomachs or digestive cavities of some invertebrates.

After dealing with the chief terms used by Aristotle to denote various parts of the alimentary canal, and briefly discussing his views on digestion, the above-mentioned descriptions and a few others of less importance will be considered.

In almost every instance in which he refers to the œsophagus, he calls it *stomachos*, and in most cases he calls the stomach *cœlia*, under which term he includes also the gizzard of a bird and the digestive cavity of an invertebrate. The usual term used for an intestine is *enteron*, but, in many passages, he uses the phrases *upper cœlia* and *lower cœlia*, the former including the stomach and the latter either the whole or a part of the intestines. He does not appear to distinguish the small from the large intestines.

Digestion was effected, according to Aristotle, wholly or almost wholly by the action of animal heat, which he believed to be different from ordinary heat, such as that from a fire. The function of the mouth, he says, is not to digest but to facilitate digestion by masticating the food.* In the stomach and part of the intestines, digestion was effected by the heat supplied, so Aristotle believed, mainly by the liver, spleen, and omentum.† He says also that the cæca found in most fishes serve to store up food which is therein putrefied and digested.‡ Evidently, therefore, he not only followed Hippocrates, who believed that digestion was due to the action of heat, but also some who believed that it was due to putrefaction.

The nutritious matters, Aristotle says, passed into the blood through numerous vessels distributed throughout the

* *P. A.* ii. c. 3, 650*a*. † *Ibid.* iii. c. 7, 670*a*, iv. c. 3, 677*b*.
‡ *Ibid.* iii. c. 14, 675*a*.

mesentery, and extending, like roots, between the intestine and the chief blood-vessels.*

The œsophagus opens into the stomach, he says, after passing through the diaphragm, and is extensible both in length and diameter; the human stomach, he adds, is like that of a dog, for it is not much wider than the intestine and looks like a wide part of the intestine.† The omentum, he says, is a fatty membrane attached along the middle of the stomach where there is, as it were, a seam of that organ, and the mesentery is a fatty membrane lying above or dorsally to the intestines.‡ The omentum, mesentery, and diaphragm are present, he says, in all animals with blood.§

Aristotle evidently never saw a human stomach, the maximum sectional area of which is decidedly greater than that of the intestines, while its form is such as to distinguish it at once from them. The omentum, by which he probably meant the great omentum, is present in mammals only, but the mesentery is found in most, if not all, vertebrates. The word used by Aristotle to denote the diaphragm is *diazoma* or sometimes *phrenes* or *hypozoma*, but each is sometimes used in a puzzling sense, for birds, reptiles, fishes, and even some invertebrates are said to have a *diazoma* or *hypozoma*. The meaning of these words can be ascertained, in such cases, only by reference to the context, and, in many cases, it is evident that they refer merely to a region of an animal's body, and not to a membrane or the like serving as a partition. Aristotle's ideas about the *diazoma* or *hypozoma*, like those of Plato, are connected with his ideas about the *soul*. In *P. A.* iii. c. 10, 672*b*, he says that all animals with blood have a *diazoma*, sometimes called *phrenes*, which is necessary for dividing the region of the nobler from that of the animal passions.

He was aware that the stomachs of various animals vary greatly in size and shape, and in the positions of the inlet of the œsophagus,‖ but his most interesting description is that relating to the stomach of a ruminant, such description being so accurate as to suggest that he dissected the stomach of one of these animals. According to him, it has four chambers of the following kind:—"Commencing at

* *P. A.* iv. c. 4, 678*a*.
† *H. A.* i. c. 13, s. 9.
‡ *Ibid.* i. c. 13, s. 10, iii. c. 11, s. 2.
§ *P. A.* iv. c. 1, 676*b*.
‖ *H. A.* ii. c. 12, s. 7; *P. A.* iii. c. 14, 675*a*.

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the mouth, the œsophagus extends to the rumen, the inside of which is rough and furrowed. To the rumen is connected, near the part where the œsophagus joins it, the reticulum, so named from its appearance, for, although it is like a stomach on its outer side, it is like the meshwork of a net on its inner side; it is much smaller than the rumen. Next to the reticulum is the psalterium, which is rough and folded on its inner side, and about as long as the reticulum. Finally, there is the abomasum, larger and longer than the psalterium; there are many delicate folds on the inner surface of the abomasum, and the intestine extends from it."* This is one of the best of Aristotle's anatomical descriptions. The four chambers, *viz.*, the rumen, reticulum, psalterium, and abomasum, are called by him the *megale Koilia*, *Kekryphalos*, *Echinos*, and *Enystron*, respectively. In *P. A.* iii. c. 14, 674*b*, he says that these chambers compensate for the want of front teeth in the upper jaws of ruminants, and that, during its passage from chamber to chamber in succession, the food is reduced to a pulp.

Some animals, according to Aristotle, have intestinal cæca, and no animal without front teeth in its upper jaw has an intestine without a cæcum. The elephant, he says, has an intestine with its parts so grown together that it seems to have four chambers for its food, and it has no receptacle for food other than these.†

Not only animals without front teeth in the upper jaw, or ruminants, but many others, *e.g.*, the horse, rabbit, rat, dog, and monkey, have a well-developed cæcum. The passage about the elephant is not clear, but it may be mentioned that the elephant has a large cæcum and, according to Owen, its duodenum is very much convoluted.

Aristotle knew that some birds have a crop, for he specially notes its presence in the domestic fowl, dove, wood pigeon, and partridge, and says that it is a large receptacle of skin in which the food is first received but not digested.‡

The proventriculus or glandular stomach of birds was known to Aristotle, but he considered it to be merely a storage chamber for food before being comminuted.§ In *H. A.* ii. c. 12, s. 15, he refers to the proventriculus in the

* *H. A.* ii. c. 12, ss. 5 and 6.
† *Ibid.* ii. c. 12, s. 8.
‡ *Ibid.* ii. c. 12, s. 14.
§ *P. A.* iii. c. 14, 674*b*.

raven, crow, quail, and owl, and his statements show that he was aware that the proventriculus was well-developed in the first three birds, and that, in the owl, it was but little wider than the œsophagus.

He says correctly that most birds have a fleshy and compact gizzard, with an inner, strong skin separable from the fleshy part.* He knew well the intestinal cæca of birds, and states correctly that they are found in most birds, are few in number, and are situated towards the termination of the intestines.† It seems strange that, while he attempts to give the numbers of the cæca in fishes, he merely says that those of birds are few in number. The cæca in birds are, as is now well known, almost always two.

He must have examined the alimentary canal of many birds, but he seems to have examined that of the quail with more than usual care. According to him, this bird has a well-marked proventriculus, and a crop which is at a great distance from the gizzard, considering the small size of the bird.‡

The proventriculus of the quail is close to the gizzard, and, when gently inflated, about four-tenths of an inch in diameter at its widest part, while the diameter of the œsophagus is about three-tenths of an inch. Its crop is a compact oval bag, and in one quail I found it to be 1·8 inches from the gizzard, which seemed to be a great distance, considering the size of the bird.

He states incorrectly that, in most fishes, the stomach is connected directly to the mouth, and that, on this account, the stomach falls forward into the mouth when they pursue smaller fishes.§

The phenomenon described here, but incorrectly explained, occurs more especially in fishes having an air bladder which does not communicate by means of a duct with the alimentary canal. When a fish passes quickly or is drawn from deep water towards the surface, the gas in its bladder expands, and may tear the bladder and even the mesentery and cause the anterior part of the alimentary canal to project into the fish's mouth.

The nature of the stomach and intestines in fishes is, he says, similar to that in snakes, for fishes have a simple stomach of different form in different fishes, for some have

* *H. A.* ii. c. 12, s. 15.
† *Ibid.* ii. c. 12, s. 17.
‡ *Ibid.* ii. c. 12, ss. 15 and 17.
§ *Ibid.* ii. 12, s. 4.

a stomach which is quite different from that of others, such as, for example, the parrot-wrasse, which is the only fish that seems to ruminate.*

In fishes, the stomach and intestines, especially the stomach, are usually more complicated in form than those in snakes. Some fishes, like the sharks, have capacious stomachs shaped like a bent tube or siphon, and many, *e.g.*, the eel and bass, have stomachs with a large cæcum. There are other forms, but these are the chief types. The stomach of the parrot-wrasse (*Skaros*) is without a cæcum, and appears to be of simpler form than that of most fishes, but I have been unable to obtain a specimen for dissection of the stomach or to find a full description of its general structure. The so-called ruminating habits of Aristotle's *Skaros* will be dealt with in Chapter xvii.

The grey mullet has a muscular stomach which serves as a powerful grinding organ, like a bird's gizzard, and Aristotle, who calls this fish *Kestreus*, was aware of this peculiarity.†

The pyloric cæca of fishes were well known to Aristotle, who says that they are situated near the stomach and may be few or many, or, in some fishes, absent.‡ The most important part of his account of the numbers of cæca in different fishes is given below.

According to Aristotle, the *Malakia* or cephalopods have a long and narrow œsophagus passing into a large crop, like that of a bird, and close to this crop is the stomach, shaped like the whorl of a whelk; from this an intestine, small

Aristotle's fishes.	Cæca.	Modern names.	Cæca.
Kestreus	Many	Grey Mullet	Six
Kobios	,,	Cottus	Four to nine
Perke	,,	Perch	Perca fluviatilis, three Serranus scriba, seven
Skorpios	,,	Scorpæna	Eight (Cuv. and Valenc.)
Trigle	,,	Red Mullet	Eight, about
Chrysophrys	Many or few	Gilt-head	Four (Cuv. and Valenc.)
Selache (most)	None	Cartilaginous fishes	None, with few, if any, exceptions.

* *H. A.* ii. c. 12, s. 13. † *P. A.* iii. c. 14, 675*a*.
‡ *H. A.* ii. c. 12, s. 13.

but wider than the œsophagus, extends backwards towards the mouth.*

This description applies very well to the alimentary canal of a sepia or loligo (calamary), except that Aristotle mistakes for a crop what is the stomach, and the stomach for an intestinal cæcum. He also states correctly that the sepia and calamary differ in the form of the above-mentioned parts, but adds incorrectly that the parts about the stomach are the same in the sepia and octopus,† for the octopus has a well-marked crop. He states correctly that the ink bag of the cephalopods serves as a means of defence, that its duct opens close to the terminal end of the intestine, and that it is largest in the sepia and situated lower down than in the octopus and calamary.‡

Aristotle's statements about the gastric teeth of crustaceans have been discussed in Chapter x. With respect to the general characters of the alimentary canal in crustaceans, he states substantially correctly that the œsophagus is short and opens into a membranous stomach, whence extends a simple intestine of uniform diameter.§

His descriptions of the alimentary canal in that section of his *Ostrakoderma* which consists of molluscs are full of difficulties. He mentions some species of Buccinum (*Keryx*), Murex or perhaps Purpura (*Porphura*), and other gastropods in his descriptions, but does not describe all the chief parts of the alimentary canal for any one of these. He gives a concise general description of the alimentary canal of a gastropod in *P. A.* iv. c. 5, 679*b*, where he states that next to the mouth is a crop, like that of a bird, then a *stomachos*, and next to this a *cœlia* or stomach in which is the *mecon* (liver), whence the intestine takes its origin. Aristotle seems to be referring to the crop, which occurs, it is true, in snails and many other gastropods, but not close to the mouth in the way which he seems to suggest. It is less likely that Aristotle refers to the buccal cavity. The relations between the stomach, intestine, and *mecon* or liver he did not understand. The stomach requires to be carefully dissected out from the enveloping mass of the liver; he does not seem to have done this, but took the whole mass for the stomach, which he says contained the *mecon*.

* *H. A.* iv. c. 1, s. 10; *P. A.* iv. c. 5, 678*b*.
† *P. A.* iv. c. 5, 678*b*. ‡ *Ibid.* iv. c. 5, 678*b* and 679*a*.
§ *H. A.* iv. c. 2, ss. 10–12; *P. A.* iv. c. 5, 679*a*.

Aristotle says that Buccinum and Murex or Purpura have a tongue-like proboscis which is hard and can bore through the shells of animals used as baits.* The last part of this statement is incorrect, for these molluscs bore mainly by means of their radulas.

The *Kochloi* which appear to have comprised the snails, *Helicidæ*, are said by him to have a stomach close to the mouth and like the crop of a bird; beneath it, he adds, are two hard, white bodies, like nipples, and from it a simple long *stomachos* extends to the *mecon* in the spiral of the shell.† What he calls the stomach seems to be the crop, and the hard, white bodies seem to be the dart sacs of the *Helicidæ*.

After describing the five teeth, constituting the chief part of what is still called "Aristotle's lantern," he says that the œsophagus of the sea-urchin leads to the stomach, with its five loops full of excreta.‡ He had evidently examined the internal organs of a sea-urchin, in which the gastro-intestinal canal is suspended, in the form of a coil with loops, from the inner sides of the shell.

According to Aristotle, most of his *Entoma* have an alimentary canal which passes directly and without divisions from the mouth to the anus, but a few have a coiled alimentary canal, and in some, *e.g.*, the locust, there is a stomach succeeded by a straight or coiled intestine.§

This is a very general description, and is not a good one. Many larvæ, myriapods, centipedes, and some others of his *Entoma* have a fairly straight, simple alimentary canal, but many of his *Entoma*, *e.g.*, beetles, bees, &c., have a complicated alimentary canal and intestinal cæca, the existence of which Aristotle does not appear to have known.

F.—The Urinogenital Organs.

It has already been shown that Aristotle believed that the blood, having left the heart, never returned, but was used up or dissipated in various ways. It is well-known that a part of the blood is removed by the action of the urinary organs, but he believed that the essential organ for the performance of this function was the bladder, and that

* *H. A.* iv. c. 4, s. 8. † *Ibid.* iv. c. 4, ss. 8 and 9.
‡ *H. A.* iv. c. 5, s. 5; *P. A.* iv. c. 5, 680*a*.
§ *H. A.* iv. c. 7, s. 7; *P. A.* iv. c. 5, 682*a*.

the kidneys merely assisted the bladder and might even be absent.*

He gives some interesting information about both the kidneys and the bladder in various animals. Referring chiefly to the human kidneys, he shows clearly that he was aware that each kidney had a hollow part and a compact vascular part, that blood-vessels, now known as the renal artery and renal vein, extend between the vascular part and the aorta and great blood-vessel, respectively, and that a strong tube, the ureter, passes from the hollow part of each kidney to the bladder.†

The human kidneys, Aristotle says, are similar to those of an ox, being made up, as it were, of many kidneys and not being compact bodies, like the kidneys of sheep or some other animals.‡ The kidneys of the human fœtus and, occasionally, those of the adult are lobulated, but they are not like the kidneys of an ox. In *P. A.* iii. c. 9, 671*b*, he says, substantially correctly, that the kidneys of a seal are like those of an ox.

He believed that all oviparous animals, except some tortoises, were without kidneys or bladder, although he speaks of some birds having certain flat, kidney-like bodies.§ The *Emys*, by which he seems to have meant the pond-tortoise, had neither kidneys nor bladder, because fluid could easily escape through the soft skin of the animal.‖ The marine tortoise, he says, is the only oviparous quadruped which has its kidneys and bladder proportional in size to the other parts of the animal, and its kidneys are, he adds, like those of oxen;¶ the land tortoises have a very small bladder, he says, and the marine tortoises, a large one.**

Kidneys are present in birds, reptiles, amphibians, and fishes, but a true urinary bladder is found in mammals only. It is evident that Aristotle believed that tortoises were the only oviparous animals in which a bladder could be said to exist, and that in land tortoises it was very small. It is well-known that a so-called urinary bladder is present in many other oviparous animals, and that the bladder is usually much larger in the land tortoises than in the marine

* *P. A.* iii. c. 7, 670*b*.
† *H. A.* i. c. 14, s. 7; *P. A.* iii. c. 9, 671*b*.
‡ *H. A.* i. c. 14, s. 7; *P. A.* iii. c. 9, 671*b*.
§ *H. A.* ii. c. 12, s. 1; *P. A.* iii. c. 9, 671*a*.
‖ *P. A.* iii. c. 9, 671*a*. ¶ *H. A.* ii. c. 12, s. 1.
** *P. A.* iii. c. 8, 671*a*.

ones. In some land tortoises the bladder is a large reservoir furnishing them with moisture when at a distance from their usual drinking places; this is well exemplified by Darwin in his *Naturalist's Voyage round the World* (2nd edition, London, 1890, p. 409). With respect to Aristotle's statement about the form of the kidneys of tortoises, it may be said that these kidneys are compact but present a series of convolutions, *e.g.*, the surface of each kidney of a small specimen of the Grecian tortoise showed a series of ridges and furrows, and, when the capsule was removed, the substance of the kidney showed the ridges and furrows very clearly indeed, the whole forming a pattern scarcely less complicated than that seen on the surface of the human brain.

Aristotle says that, in all animals, the right kidney is higher or more forward than the left, and is drier and less fatty.* The right kidney is generally nearer the head than the left in mammals and in the grass-snake and some other snakes. In Man and the pig the left kidney is often a little nearer the head than the right, while the kidneys of most birds, of some pigs and sheep, and of the frog and some other animals, are as nearly as possible symmetrical in position. The amount of fat about the kidneys varies much, even in individuals of the same species. In sheep, pigs, and some other animals, it may be said that, when the kidneys are unsymmetrical in position, the amount of fat about the one which is nearer the head is greater than that about the other.

It has been shown how, contrary to the modern opinion, Aristotle subordinated the kidneys to the bladder; in a somewhat similar way he subordinated the testes to the seminal ducts. This will be clear from the following epitome of *G. A.* i. c. 4:—The testes are not necessary for reproductive purposes, for, if they were, they would be found in all animals which reproduce. Now, neither snakes nor fishes have testes, yet their *poroi* (ducts) are full of semen. The testes, in fact, serve a kind of regulating purpose only, and are not parts of the *poroi*, but attachments, just like the stones which weavers attach to the warp, and, when the testes are removed, the *poroi* are withdrawn backwards. Hence, in such a case, the *poroi* are withdrawn and the animal becomes impotent, but, in one instance, a bull was temporarily potent because the *poroi* were not withdrawn.

* *H. A.* i. c. 14, s. 7.

Evidently, therefore, the organs serving to secrete the semen were, according to him, the seminal ducts, and the testes were adjuncts sufficiently important, in some cases, to ensure their efficiency. In some cases, the ducts could act without the aid of the testes, for, in many passages, he makes it clear that there were no organs to which he could give the name testes in some animals, *viz.*, in snakes, fishes, and all animals with gills.* He was probably deceived mainly by the usually elongated and duct-like form of the testes in these animals. Cartilaginous fishes usually have testes of a compact form, but it is not clear whether he intended to include these fishes within the meaning of the passages above cited. Probably he did not, for he often describes the cartilaginous fishes as if they were a separate and distinct group.

In a long series of passages in *H. A.* iii. c. 1, ss. 7-9, Aristotle gives a remarkable description of the anatomy of the testes of what are now called mammals, and exemplifies his meaning by reference to a drawing, which has been lost. This description was evidently based on one or more dissections. Notwithstanding many difficulties in the Greek text, it is evident that he had some knowledge of the spermatic arteries, the epididymis, the vas deferens and its communication with the urethra, and the tunica vaginalis, part of which envelops the epididymis. He states that the testes are not of flesh, but are nearly of the nature of flesh.† The second part of this statement is incorrect; each testis is composed chiefly of a very large number of seminiferous tubules, enclosed within a strong, white, fibrous envelope.

Among the numerous statements he makes about the male organs of particular kinds of animals are some of special interest. He says that the testes of the elephant are near the kidneys,‡ and that the testes of some animals, *e.g.*, the lizard, tortoise, crocodile, and hedgehog, are in the region of the kidneys, but some have them near the abdominal wall, like the dolphin and elephant.§

The first statement, relating to the elephant, is quite correct, for, according to Dr. M. Watson, the testes, which are nearly globular, lie below the posterior ends of the kidneys.‖ The testes of the dolphin are abdominal, and lie

* *H. A.* ii. c. 9, ss. 1 and 2, ii. c. 12, s. 10, iii. c. 1, s. 1; *P. A.* iv. c. 13, 697*a*; *G. A.* i. c. 3, 716*b*.

† *H. A.* i. c. 10, s. 4. ‡ *Ibid.* ii. c. 3, s. 4. § *Ibid.* iii. c. 1, s. 2.

‖ *Journ. Anat. and Physiol.* vol. vii. 1873, p. 65.

far back. Those of the hedgehog undergo, as is well known a great change both in position and size, according to the time of year. Aristotle's statements about the testes of the lizard, tortoise, and crocodile are substantially correct.

His statements about the *os penis* of the marten and other animals have been discussed in Chapter x.

Much has been written about the hectocotylus of the argonaut, octopus, and other cephalopods, which is an arm specially modified for the purpose of conveying the spermatozoa to the female. Aristotle was the first to describe this organ and to suggest its proper function. He says, speaking particularly of an octopus: "Some say that the male has some kind of external generative organ in one of its arms, on which are two very large suckers, that such organ is sinewy, as it were, as far as the middle of the arm, and that the whole of it is sent into the funnel of the female."* The male, he says, differs from the female in having a longer head and the part of the arm, called the generative organ by fishermen, is white.† The last of its arms, he says, is the most pointed of all, is the only one which is whitish, and is used in copulation.‡ Finally, he says that the male must approach the funnel of the female, whether he emits semen, a part [of his body], or any other agent, and that the insertion of that arm of the octopus, which fishermen say is used in copulation, through the funnel is for the sake of an intertwining and not for the purpose of an organ of generation, for it is outside the funnel and body of the female.§

It is clear, therefore, that he believed, on the authority of fishermen, that the strangely modified arm was an organ of generation. There does not seem to be sufficient evidence to show that he knew of the free or so-called autotomous hectocotylus of the argonaut and some other cephalopods. The cephalopod to which his descriptions were intended to refer is generally admitted to be *Octopus vulgaris* of the Mediterranean. A description of the hectocotylised arm of this cephalopod is given in *Ann. Mag. Nat. Hist.* (2), xx. pp. 98–9, where it is said that the arm is short and pointed at its end, and that it has a very white fold of skin on its dorsal side and sometimes one or two exceptionally large suckers. If this description is compared with Aristotle's,

* *H. A.* v. c. 5, s. 1.
† *Ibid.* v. c. 10, s. 1.
‡ *Ibid.* iv. c. 1, s. 6.
§ *G. A.* i. c. 15, 720*b*.

it will be evident that this cephalopod was carefully examined by him.

The very well-known account, given in Owen's *Anat. Invertebr.*, 1855, pp. 630-1, and in many other zoological works, of the way in which several investigators rediscovered the hectocotylus and determined its nature, reads like a romance. A comparison of the views of some of these investigators with those expressed by Aristotle should increase his reputation as an investigator.

Aristotle noticed the vasa deferentia of the *Karides*, crustaceans which cannot be identified satisfactorily but seem to have comprised prawns and shrimps, for he says that the males have two coiled, white tubes extending from the bases of the last pair of legs into the body.* The rest of his description is not clear, but he seems to have believed erroneously that seminal ducts extended alongside the intestine from the coiled tubes to the telson. This is borne out by his statement that in the male *Karabos*, or spiny lobster, ducts containing seminal fluid extend to the anus from the thoracic part.†

It has been stated already that the two hard white bodies below the crop of the *Kochlos*‡ were probably the dart sacs, but Aristotle did not understand their sexual functions. He did not consider his *Ostrakoderma* to have any separate male seminal organs. This seems to be a fair conclusion from the numerous statements which he makes. One of these may be specially cited. In *G. A.* iii. c. 11, 761*b*, he says that Buccinum, Murex, and others said to make cells like bee-hives, or egg-cases, eject a sticky fluid from something of a spermatic nature, but that we ought not to consider this to be semen but something which, in a sense, partakes of the nature of what is in plants.

He recognized that there was a distinction of sexes in some of his *Entoma*, but be does not seem to have believed that the males had any seminal ducts. He says distinctly that, among those which copulate, the males do not appear to have any seminal ducts.§ The idea that sexual generation under such circumstances could take place may seem to be strange, but it will be seen from Chapter xiv. that it was in accordance with some of Aristotle's views on generation.

When describing the female organs, Aristotle repeatedly uses an important anatomical term, viz., *hystera*, to denote

* *H. A.* iv. c. 2, s. 13.
† *Ibid.* iv. c. 2, s. 12
‡ *Ibid.* iv. c. 4, s. 8.
§ *G. A.* i. c. 16, 721*a*.

one or more parts of these organs. That the *hystera* is internal is clear from many passages, and especially from *G. A.* i. c. 12, 719*a*, where it is stated that the *hystera* is internal in all females, because of the need for guarding the young animal and keeping it warm. Its meaning is clear to this limited extent, but it is often difficult to decide to what part or parts the term refers. In some cases it means the uterus of a mammal, *e.g.*, in *H. A.* vii. c. 4, s. 1, but in many other passages it means the ovaries, or these and the oviducts, of birds, reptiles, amphibians, fishes, cephalopods, and crustaceans.

Even when describing the organs of mammals he does not always distinguish between the uterus and the ovaries, and, in *G. A.* i. c. 3, 716*b*, he says that all *hysteræ* are in two parts, just as there are two testes in males. He also mentions the *hysteræ* in close connection and by way of comparison with the testes. His fullest description of the uterus of a mammal is in *H. A.* iii. c. 1, ss. 10 and 11. It seems to be clear that he gave the name *hystera* more particularly to the more external and the name *delphys* to the innermost parts of the uterus, and that he was acquainted with the cornua or horns of the uterus in some animals, and with the twisted or waved parts of the Fallopian tubes or oviducts.

One of the most interesting passages relating to the *hystera* of viviparous animals is that in which he records the existence of placental animals. He says that the *hysteræ* of ruminants and also the hare, mouse, and bat, among animals with front teeth in both jaws, have *cotyledones* (placentæ) in the pregnant *hystera*, and that all other viviparous animals with feet and with front teeth in both jaws have a smooth *hystera*, the fœtus being attached to the *hystera* itself and not to a *cotyledon*.*

The animals in which the placentæ are restricted to circumscribed patches are much more numerous than Aristotle believed, and among them may be specially mentioned, in addition to those mentioned by Aristotle, the Carnivora and Insectivora.

In his short descriptions of the *hysteræ* of birds, reptiles, batrachians, and cartilaginous fishes, in *H. A.* iii. c. 1, ss. 12 and 13, he clearly refers to the oviducts communicating with a single passage leading to the exterior.

* *H. A.* iii. c. 1, s. 15.

He did not believe that fishes had any visible external passages from the generative organs.* In cartilaginous fishes, the genital passages open into a cloaca, but in most bony fishes the external passages from the generative organs are visible behind the anus, and may be readily seen in the bass, gurnard, silurus, and salmon.

Aristotle's descriptions of the female generative organs of the invertebrata are sometimes very difficult to understand at all. They were probably based on dissections, but it is almost certain that the parts were not dissected out at all clearly.

He misunderstood the arrangement of the female organs of crustaceans in much the same way as he misunderstood the arrangement of the male organs, for he speaks of the oviducts extending along the intestine and opening outwards somewhere on the telson.†

The female octopus, he says, has an ὠόν, meaning probably the ovarium, uneven outside, smooth and white inside, and containing a very large quantity of eggs; in *Sepia*, he says, there are two such ovaria, also containing many white eggs.‡ This appears to be his meaning, but it is difficult to understand, for the eggs are contained in ovisacs projecting from the interior surface of the ovarium, and no cephalopod seems to have more than one ovarium; *Sepia* has one oviduct while *Octopus* has two.

There are many other statements about the generative parts of these and other invertebrata, and, among these, may be specially mentioned the one in which he correctly records the number of the ovaria in *Echinus*, for he says that they are five in number.§

He gives some information, chiefly in *H. A.* ii. c. 3, about the teats of various animals. He states correctly that the elephant has two teats between its fore legs, and that the camel and leopardess have four each, but gives the number of teats in the bear as four instead of six, and that in the lioness as two instead of four.

He shows that he had examined the dolphin carefully, for he says that this animal has two mammæ, not in its anterior part but near its genitals, that it has no visible teats, but two ducts, as it were, one on each side, from which the milk flows, being sucked by the young ones as they follow their mother, and that this had been clearly seen by some

* *H. A.* ii. c. 9, s. 2. † *Ibid.* iv. c. 2, ss. 12 and 13.
‡ *Ibid.* iv. c. 1, ss. 13 and 14. § *Ibid.* iv. c. 5, s. 5.

people.* These statements are substantially correct. According to Cuvier, there are two mammæ, whence milk flows through nipples situated in little pits (fossettes), one on each side of the vulva.†

Male solid-hoofed animals have no teats, Aristotle says, except those which resemble their dams, a phenomenon which is seen in horses.‡ The horse is one of the comparatively few animals in which the males are without teats, but John Hunter found traces of them in some stallions.§

The above comprise the most interesting parts of Aristotle's researches on the urinogenital organs. There are many others in various parts of his works, but those discussed are sufficient, perhaps, to represent fairly the value of his researches.

* *H. A.* ii. c. 9, s. 1.

† *Leçons d'Anat. Compar.*, 2nd edition, Paris, vol. viii. 1846, pp. 604 and 608.

‡ *H. A.* ii. c. 3, s. 2.

§ *The Works of John Hunter*, edit. by J. F. Palmer, 1835–7, vol. iv. p. 37.

CHAPTER XII.

ARISTOTLE'S ANHOMŒOMERIA AND THEIR FUNCTIONS (*continued*).

G.—The Brain and Spinal Cord.

Aristotle's views on the nature and functions of some important organs of animals were very different from modern views on the same subjects. This has been made clear in the preceding chapters and is strikingly exemplified by his views on the brain and spinal cord.

He believed that the brain was not a centre of sensation, but a cooling means adapted to moderate the heat of the body and to aid, or render more certain, the action of the sensory organs, while the spinal marrow, being of a hot nature, moderated the action of the brain. Such, speaking generally, were his views.

Some philosophers, he says, believe that sensation resides in the brain, but this is not true, for, since the brain is quite devoid of feeling, it cannot be a cause of sensation; the philosophers referred to are aware that the brain is the most peculiar organ of the body, and that some of the sense organs are lodged in the head. They cannot, he adds, find out the cause of this, yet infer that the brain and sensation are associated together, but it has been shown already that the heart is the sensory centre.*

Among philosophers who believed that the brain was the centre of sensation were Diogenes of Apollonia and Alcmæon. Aristotle clearly suggests that they reasoned on insufficient data. He himself considered their views and rejected them. His investigation and process of reasoning about this subject exemplify both the excellences and defects of his method. His observations on the brain, in one or more animals, led him to believe that it was cold, that its substance was bloodless, and that it was devoid of sensation; he also concluded that the brain was found in animals with

* *P. A.* ii. c. 10, 656*a*.

blood, and that a brain or anything analogous to a brain was not found in other animals, except the cephalopods.* Sensation he believed to be manifested more especially in parts with blood, and, in one passage, which seems to be an interpolation, it is stated that no part that is without blood has sensation.† This passage must be read, however, in conjunction with many other passages showing that he meant that no part that is without blood or what is analogous to blood manifests sensation, for his so-called bloodless animals have sensitive parts. He recognized, however, an apparent connection between sensation and the presence of blood, and, reasoning consistently, concluded that the brain, cold, bloodless, devoid of sensation, and absent from many animals which manifested sensation, could not be the sensory centre.

So far, his reasoning, although based on false data, is quite intelligible. There remain, however, a series of statements which are not always consistent and are difficult to understand. A strong argument in favour of the view that the brain is the sensory centre is that it is connected with the sense organs by what are now called nerves. Now Aristotle concluded, and adduced arguments to support his conclusion, that the brain was not connected with the sense organs. He says: "It is clear from inspection and still more from its being insensible when touched that the brain has no unbroken connection (συνέχεια) with sensory organs."‡ Yet there are a few passages which suggest, and one which seems to show, that he noticed such a connection, but he did not admit that the connection was with the brain, but with the blood-vessels about the brain. These passages will next be discussed.

He says: "Three ducts (πόροι) extend from each eye to the brain, the largest and the medium-sized one to the cerebellum, and the smallest, which is nearest the nose, to the brain itself. The largest ducts lie side by side and do not come into contact with each other, but the medium-sized ones do so; this is especially evident in fishes, for the medium-sized ducts are nearer the brain than the largest, and the smallest are very much separated from each other and do not come into contact."§

* *P. A.* ii. c. 7, 652*b*; *H. A.* iii. c. 14, s. 1, and in many other passages in his works.

† *P. A.* ii. c. 10, 656*b*.

‡ *Ibid.* ii. c. 7, 652*b*.

§ *H. A.* i. c. 13, s. 4.

The medium-sized ducts may be the optic nerves, except that they are said to pass to the cerebellum. Aristotle says that they come into contact with, or fall on, each other (*sympiptousi*), and that this is well seen in fishes, suggesting that he had seen the meeting or crossing of the optic nerves. Aristotle's description is insufficient for the determination of the other ducts. Dissections of various animals, especially fishes, made for the purpose of determining these ducts, have not enabled me to arrive at a conclusion.

The next passage to be considered is much less ambiguous. Aristotle says: "The brain of the chamæleon is a little above its eyes and continuous (συνεχής) with them."* This shows as clearly as any passage can be expected to do that he saw the optic nerves of the chamæleon to their full extent, yet, as has been stated already, he did not admit that the brain was in unbroken connection with the sense organs. He did not understand the nature of the nerves which he saw. On the contrary, it seems that he considered them to be ducts conveying nutriment or other fluid, for he says that the purest of the moisture about the brain is separated through the ducts which are seen to lead from the eyes to the membrane about the brain.†

Not one of the passages relating to the ducts between the brain and sense organs is as clear as that already given about the chamæleon. It seems strange that, after having exposed the optic nerve by dissection in the way which that passage suggests, he should have adhered to his belief in the want of an unbroken connection between the substance of the brain and any of the sense organs.

There are a few other passages which are difficult and are consistent only in showing that he did not believe in such a connection. In *H. A.* i. c. 9, s. 1, it is stated that no duct (πόρος) extends from the brain to either ear, but a blood-vessel extends from the brain to each ear; in *P. A.* ii. c. 10, 656*b*, however, it is stated that a duct extends from each ear to the back part of the head. The effect of the various passages previously cited is to show that the ducts, whatever their real nature may be, do not lead to the substance of the brain, but to some part of the blood system, and so communicate with the heart, Aristotle's centre of sensation.

There is an interesting passage which bears upon the

* *H. A.* ii. c. 7, s. 5. † *G. A.* ii. c. 6, 744*a*.

question of the extent of Aristotle's knowledge of what are now called nerves. In that passage he says: "Numbness does not affect any part of the body where there is no νεῦρον."* This statement, at first sight, might seem to be evidence of an important discovery, but it has already been shown how unlikely it is that he ever distinguished nerves from sinews (νεῦρα). This distinction was first effected, to some extent, by Erasistratus and Herophilus, and more fully by Rufus Ephesius and Galen.

Aristotle, giving his own views on the functions of the brain, says that Nature has arranged that it should act in opposition to the heart, which is hot, and so regulate it, and has formed the brain of material which is earthy and watery and therefore adapted to have a cooling effect.† The brain, according to him, exercises a very important function in connection with the heart, and is one of the most important organs of the body; he says that it is reasonable that the membranes about the brain and the heart should be very strong and stout, because the heart and brain require most protection, since they are the chief regulating powers of life.‡ That the brain, under the influence of pain, grief, or pleasure, exercises a marked effect on the heart is very well known. Aristotle points this out very clearly, although he does not correctly explain it. He says that the heart is very much influenced by the smallest change in the blood on the outer surface of the brain.§

The sensory organs which he considered to be more reliable than the others are usually situated in the head, for they are rendered more certain in their action, he says, in consequence of their being supplied with the purest blood; the effect of the action of hot blood would also be to impair the action of the sensory organs, and the eyes in particular are in the head because, he says in effect, both the brain and the eyes are of the nature of water.‖

Aristotle's views on the functions of the brain, therefore, are not fairly represented by stating that the brain is a cooling means, and still less fairly by stating, as Galen seems to do,¶ that Aristotle considered the brain to be a mere sponge, as it were, saturated with water. On the contrary, he assigned to it very important functions in connection

* *H. A.* iii. c. 5, s. 4.
† *P. A.* ii. c. 7, 652*b*.
‡ *Ibid.* iii. c. 11, 673*b*.
§ *Ibid.* ii. c. 7, 653*b*.
‖ *Ibid.* ii. c. 10, 656*b*; *De Sensu, &c.*, c. 2, 438*a*.
¶ *De Usu Partium, &c.*, viii. c. 3.

with the sensory organs, and considered it to be a peculiar organ second in importance only to the heart.

His views on the spinal marrow were almost entirely erroneous. He considered it to be different from ordinary marrow, but decided that it required to be composed of a glutinous and sinewy substance, to enable it to assist in holding the vertebræ together.* He says that there were some who, seeing that the brain and spinal marrow were continuous, concluded that the brain consisted of marrow, but, he says, they are quite different in character, the marrow being hot and the brain cold, so that the marrow moderates the action of the brain.†

Aristotle gives some interesting information about the brain and its membranes in certain animals. In Man, and other animals which have a brain, he says, it lies in the front part of the head, the back of the head being empty to an extent varying with the size of the animal, but Man has a brain which, considering his size, is larger and moister than that of any other animal.‡

His views on the nature of the organ of hearing probably induced him to believe in the existence of an air cavity in the back of the head, for he says that the so-called empty space at the back of the head contains air, that the organ of hearing is of air, and that a duct connects each ear with the back of the head.§ He may also have been influenced by statements, in a treatise by Hippocrates,‖ and one probably by a contemporary of Hippocrates,¶ that the brain lies more towards the front than the back of the head, which contains only a small amount of brain.

His estimate of the relative size of the human brain is not quite true. The average weight of the brain of an adult man to his total weight is as 1 to 45 about; the corresponding ratios for the long-tailed field mouse, house martin, and sparrow are about 1 to 30, 1 to 33, and 1 to 30 respectively, and the brain of the goldfinch or the blue tit is relatively still larger. It will be seen that all these are small animals.

It is not true that the brain of Man is moister than that of other animals, but Aristotle's statement is in accordance with his ideas of the cooling function of the brain. Dr.

* *P. A.* ii. c. 6, 651*b* and 652*a*. † *Ibid.* ii. c. 7, 652*a*.
‡ *H. A.* i. c. 7, i. c. 13, s. 2; *P. A.* ii. c. 7, 653*a*.
§ *P. A.* ii. c. 10, 656*b*. ‖ *On Wounds in the Head*, c. 2.
¶ *On Diseases*, ii. c. 8.

Ogle suggests that the statement is based on an examination of the fœtal brain.* It is practically certain that Aristotle did not examine an adult human brain, but he may have examined the brain of some animal in which brain a rapid decomposition had set in. I have been informed of a case in which, the brain pan having been removed for the purpose of taking out the brain from a comparatively fresh body, a large part of the brain flowed away.

Aristotle states that there are two membranes about the brain, a weaker vascular one about the brain itself and a stronger one next the bone; that the brain is divided into right and left halves; that the cerebellum at the extreme end of it differs in appearance and texture from the rest of the brain; and that, in most animals, there is a small cavity in the middle of the brain.†

There are three membranes about the brain, the innermost being the pia mater, which is intimately associated with the arachnoid membrane or middle membrane, and the outermost being the dura mater. Aristotle probably saw the strong dura mater, and the other two membranes, these two delicate membranes constituting his inner membrane. The cerebellum is somewhat darker than the rest of the brain, and is striated or ribbed externally, while in form it is quite different, as Aristotle says, from the rest of the brain. The statement about the small cavity in the middle of the brain is true as far as it goes. In vertebrates, there are cavities or ventricles (four in Man) within the brain and in communication with one another.

In several passages he makes it clear that he believed that the substance of the brain was quite bloodless.‡ This belief has been used against him by some of his critics.

It is clear from several passages, *e. g.*, *H. A.* iii. c. 3, s. 7, that he knew of the presence of blood and blood-vessels in the membranes about the brain, and he says that the brain itself is bloodless, so that he evidently refers to the brain divested of its membranes. This does not, however, overcome the difficulty, for if the brain of a mammal, such as a sheep or rabbit, be examined, after removal of the membranes and careful washing, small blood-vessels can be seen extending some distance into it. Some have suggested that Aristotle made his observations only on the brain of an

* *Aristotle on the Parts of Animals*, 1882, p. 165.
† *H. A.* i. c. 13, ss. 2 and 3, iii. c. 11, s. 1.
‡ *H. A.* i. c. 13, s. 3, iii. c. 3, s. 8; *P. A.* ii. c. 7, 652*a*.

animal which had been cooked, or on the brain of some reptile or fish.

It has been mentioned already, in this chapter, that only in his *Malakia* (cephalopods) did he find, among his *Anaima*, anything corresponding with a brain. His knowledge of the cephalopods was extensive and he is quite right in his statement about the brain of these animals, which have a part of their nervous system concentrated into a mass protected by a cartilaginous case, the whole appearing like a rudimentary brain and skull. The cartilaginous case is referred to by him in *H. A.* iv. c. 1, s. 9.

H.—The Senses and Sensory Organs.

Aristotle argues that there are not more than five senses, *viz.*, sight, hearing, smell, taste, and touch, and says that some animals have all these but others have only some of them, among those which have all the senses being Man and viviparous animals with blood, with some possible exceptions, such as, for example, the *Aspalax* or mole.*

He distinguished between sight, hearing, and smell, acting through some medium, *e.g.*, air, between the subject and the object of sensation, and taste and touch, which are less dependent on the presence of such a medium. It will be convenient, in discussing his views, to deal with touch and taste first, and then smell, hearing, and sight.

According to Aristotle, touch is the primary sense, apparently because it is present in all animals and enables us to appreciate differences in the elementary qualities of matter, such as solidity and temperature.† Although he considers it to be the primary sense, he discusses whether it is not several senses rather than one, being the least simple of the senses, for, unlike the eye, which distinguishes differences in colour, or the ear, which distinguishes differences in tone, the tactile organ, whatever it may be, distinguishes differences in many qualities, and he suggests that, while sight and hearing seem to be distinct senses because their media are distinct, touch may be made up of several senses blended, as it were, in consequence of their having a common medium.‡

* *De Anima*, iii. c. 1, 424*b* and 425*a*, ii. c. 2, 413*b* and 414*a*; *H. A.* iv. c. 8, s. 1.

† *P. A.* ii. c. 8, 653*b*; *De Anima*, ii. c. 2, 413*b*, ii. c. 11, 422*b*.

‡ *P. A.* ii. c. 1, 647*a*; *De Anima*, ii. c. 11, 422*b*.

He often discusses the question of the nature and position of the organ of touch, but nowhere does he seem to arrive at a definite conclusion. Flesh or something analogous to it is, he says, the chief organ of touch, either in the same way as the eye is the organ of sight or else it corresponds with the eye together with some transparent medium.* He prefers to believe that touch does not act by direct contact, that the true organ of touch is not the flesh, but something internal to this, and he instances what happens when the hand, covered by a stretched membrane, touches some object; in this case, the object is felt, but the membrane is not, on that account, the organ of touch, but is merely a medium.† He also points out that, in other respects, there is not necessarily direct contact between the flesh and the object any more than there is contact between water and a body immersed therein, for a film of air may be between the water and the body.‡

According to Aristotle, the sense of touch is closely connected with the heart.§ It has already been explained that he did not believe that the brain was the sensory centre, and that he had no knowledge of the functions of nerves. From the modern views on the dependence of sensations of touch on the presence of tactile organs beneath the skin and in communication with the central nervous system Aristotle's views were very far removed.

Taste is, according to Aristotle, a kind of touch, for, like touch, it does not require the interposition of a medium such as is necessary between a coloured body and the eye.‖ He also considered the heart or the region of the heart to be the chief sensory organ both of taste and touch.¶

There is a close relationship, it is true, between taste and touch, which Aristotle could not have known. This relationship is that shown by the fact that the sensory nerves of the tongue are both gustatory and tactile.

He says that while, in some animals, there are two eyes, two ears, and two nostrils symmetrically placed, this double nature of the sense organs is not evident in the case of touch, but is indicated in the case of taste, for some animals, *e.g.*, snakes, lizards, and seals have a forked tongue.**

* *P. A.* ii. c. 8, 653*b*. † *De Anima*, ii. c. 11, 423*a* and *b*. ‡ *Ibid.*
§ *De Sensu, &c.*, c. 2, 439*a*; *P. A.* ii. c. 10, 656*a*.
‖ *P. A.* ii. c. 10, 657*a*; *De Anima*, ii. c. 10, 422*a*.
¶ *De Sensu, &c.*, c. 2, 439*a*; *P. A.* ii. c. 10, 656*a*.
** *P. A.* ii. c. 10, 657*a*, ii. c. 17, 660*b*, iv. c. 11, 691*a*.

It is well known that snakes and many lizards have forked tongues, and seals have a deeply notched tongue.

The sense of taste, he says, is in the tip of the tongue, for if anything is placed on the flat part of the tongue, the sense of taste is not so delicate.*

This statement needs to be modified. The sense of taste, as far as the tongue is concerned, is developed most in the upper part of the back of the tongue, and in its tip and marginal parts. The middle part of the tongue is but slightly sensitive, and this may be readily proved by placing a little salt, chamomile infusion, or sugar thereon.

He states that the tongue of the *Iynx* (wryneck) is peculiar, being like that of snakes, for its length, when extended, is equal to four fingers' breadth.† Except that the tongue of the wryneck is not forked, but vermiform, these statements are correct.

He believed that birds with the broadest tongues could talk.‡ Birds of prey, he says, generally have broad tongues, and so has the *Psittake* (parrot), an Indian bird, which is said to have a tongue like that of a man.§

He makes inconsistent statements about the tongue of the crocodile. In *P. A.* iv. c. 11, 690*b*, he seems to say that it has no tongue, but, in *P. A.* ii. c. 17, 660*b*, he admits the presence of a tongue adherent to the lower jaw. This statement is correct, for the crocodile has a large tongue attached to the floor of the mouth in such a way that it cannot be protruded but only raised.

The tongue of the chamæleon is very peculiar, being very long, extensible, and clubbed at the free end, but, strange to say, Aristotle says nothing about this, although he knew this animal very well indeed.

He says that fishes have a sense of taste, for many of them delight in particular kinds of food, but that the tongue of fishes is indistinct, being bony and adherent to the mouth.‖

It is not clear why Aristotle makes so little of the tongue in fishes. The tongue is very conspicuous in many fishes, *e.g.*, the conger and bass, with which he was very well acquainted. In one bass, a 4-lb. fish, I found that the free part of the tongue was wide and thick, and nearly an inch long.

* *H. A.* i. c. 9, s. 6. † *Ibid.* ii. c. 8, s. 2.
‡ *P. A.* ii. c. 17, 660*a*. § *H. A.* viii. c. 14, s. 6.
‖ *H. A.* iv. c. 8, s. 4; *P. A.* iv. c. 11, 690*b*.

He says that the *Kyprinos* (carp) has its palate so fleshy that it might be mistaken for a tongue.* He is referring to the fleshy and sensitive pad which is found at the back part of the palate of this fish.

He refers to what he calls the tongue or tongue-like part of cephalopods, molluscs, crustaceans, insects, and other invertebrates,† but it is not always clear to what parts he is referring. In some cases, he evidently refers to the odontophore in molluscs, and the proboscis in insects.

The olfactory organ in animals with lungs was, according to Aristotle, the nose, but, in animals without lungs, the place of this was taken by the gills, or, in insects, by the *hypozoma*, or part of the body between the thorax and abdomen.‡ All these organs corresponded with one another in being cooling organs, and, since the nose was clearly an organ of smell, Aristotle probably reasoned by analogy and concluded that the gills and *hypozoma* were also organs of smell.

Fishes, he says, clearly have a sense of smell, for most fishes are attracted by fresh baits only, and some are taken by means of baits having a particular smell.§ They have, he says, no visible organs of smell nor visible olfactory passages.‖ He refers, however, to certain ducts which appeared to be in the place of nostrils;¶ these ducts are now known to be the external olfactory passages of fishes, but Aristotle misunderstood their nature.

Cephalopods, crustaceans, and insects and other animals belonging to his *Entoma* have, he states correctly, a sense of smell, and he specially refers to the keenness of the sense of smell in bees.**

Aristotle's views on the manner in which the presence of an odoriferous substance is detected are not clearly expressed. It appears, however, particularly from *De Anima*, ii. c. 7, 419*a*, that he believed that the odoriferous substance affected the medium, such as, for example, air or water, which then affected the sense organ, the medium having a property which had a relation to smell similar to that which Aristotle's *Diaphanous* had to vision. He himself says that this property has no distinctive name, but, according to

* *H. A.* iv. c. 8, s. 4; *P. A.* ii. c. 17, 660*b*.
† *P. A.* iv. c. 5; *H. A.* iv. cc. 1–5.
‡ *P. A.* ii. c. 16, 659*b*. § *H. A.* iv. c. 8, ss. 11–13.
‖ *H. A.* ii. c. 9, s. 6; *P. A.* ii. c. 10, 656*a*.
¶ *H. A.* iv. c. 8, s. 5. ** *Ibid.* iv. c. 8, s. 15.

Suidas, Theophrastus called it τὸ διόσμον, usually translated the *transolfacient*. In a somewhat similar way, Aristotle seems to have believed that air had a quality, to which he gave no distinctive name, enabling the air to transmit sound.* Theophrastus is said to have given to this quality the name τὸ διηχές, usually translated the *trans-sonant*.

By reference to some of the main structures of the ear, Aristotle gives a more practical explanation of the act of hearing. He says, in effect, that the motion of sound is communicated through the air to the ear, the air acting like a body which is συνεχές, or made up of matter without any intervening spaces. The air then transmits its motion to the air enclosed within the coiled passage of the inner ear by the tympanum.†

The ear is able to discriminate clearly different motions transmitted through the air, Aristotle says, because the air within it is normally at rest or nearly so.‡ In a similar way, he believed that the other sense organs were normally in what may be called a neutral or balanced condition (μεσότης), with respect to the influences by which they were excited.§

He does not say much about the anatomy of the ear. After confuting a strange belief of Alcmæon that goats breathe through their ears, he says that the outer ear is formed of flesh and cartilage, that the internal ear is of coiled form, and that there is no duct from the ear to the brain, but one to the chamber of the mouth.‖ This seems to show that he was aware of the existence of what is now known as the Eustachian canal, afterwards rediscovered by Eustachius of Salerno (1500–74).

He knew that dolphins, fishes, and many other aquatic animals could hear, but says that they had no evident organs of hearing.¶ The existence of the internal ears of these animals seems to have escaped his notice (although he knew of the existence of otoliths in fishes), and nowhere does he explain the manner in which they heard.

Aristotle says that some people, dwelling near the sea, asserted that fishes could hear better than other animals, and that those fishes which could hear best were the grey mullet, bass, and certain fishes called *Chremps*, *Chromis*,

* *De Anima*, ii. c. 7, 419*a*.
‡ *Ibid.* ii. c. 8, 420*a*.
‖ *H. A.* i. c. 9, s. 1.
† *Ibid.* ii. c. 8, 419*b* and 420*a*.
§ *Ibid.* ii. c. 11, 424*a*.
¶ *Ibid.* iv. c. 8, ss. 5–9, ii. c. 9, s. 6.

and *Salpe*.* He refers to the otoliths in fishes, citing the *Labrax* (bass), *Phagros* (common pagre), *Chromis*, and *Skiaina*, and says that these fishes suffer most in winter, the otoliths having a cooling effect on their heads.†

His records of otoliths are interesting. The bass has ear-stones or otoliths which are elongated, hollowed, and waved or notched at their edges; one from a 4-lb. bass I found to be five-eighths of an inch long. I do not know anything about the ear-stones of the pagre, but those of the *Sciænidæ*, to which Aristotle's *Chromis* and *Skiaina* probably belong, are remarkable for their large size (Cuvier and Valenciennes, *Hist. des Poissons*, vol. v. p. 8), and those of *Plagioscion surinamensis*, a freshwater sciænid from British Guiana, are represented in *The Zoologist*, 1910, p. 293, and are both long and broad.

Sight was, according to Aristotle, a sense of a particularly special or distinct nature.‡ His meaning is expressed in *De Anima*, ii. c. 6, 418*a*, where he says that some qualities of objects are perceived by certain senses only, and not by others, *e.g.*, colour is the peculiar exciting cause of sight, and sound is that of hearing, but heat and cold, hardness and softness can be readily perceived by means of the tongue as well as the external skin.

Sight, he says, is more important for the practical purposes of life, while hearing is of most use for training the mind.§

It seems strange, at first, that Aristotle should place hearing before sight for educational purposes, but there is much good reason for this, for, among the ancient Greeks, recitation, the cultivation of the memory, and the practice of music were of great educational value. To-day, the imperative necessity for repeatedly using the eyes for reading and writing and for making observations has caused the possession of sight to be more important than that of any other sense for educational purposes.

Aristotle's views on light and colour have been discussed already in Chapter iv. It is there explained that he believed that air, water, and all other bodies, in a greater or less degree, have a something or quality which he called the *Diaphanous*. He had no knowledge of the functions of the optic nerves, but considered that colour caused move-

* *H. A.* iv. c. 8, s. 10.
† *Ibid.* viii. c. 20, s. 5.
‡ *De Anima*, iii. c. 3, 429*a*.
§ *De Sensu, &c.*, c. 1, 437*a*.

ments in the medium, *e.g.*, air or water, which acted on the eye by the agency of the *Diaphanous*.* He believed that the eye was of *water*, a proof being that water ran from it, when ruptured, but he did not believe that the eye was capable of sight because of this presence of water, except in so far as it was transparent. In this respect, air would have been as efficient, but Aristotle believed that the eye was of *water* because this is less yielding, and is also more easily confined than air.†

Aristotle knew very little of the anatomy of the eye, beyond certain parts which were evident on cursory examination, *viz.*, the pupil, the iris, the white sclerotic, the aqueous or the vitreous humour, or both, and the nictitating membrane of some animals.

All viviparous animals, he says, except the *Aspalax* (mole), have eyes, for the *Aspalax* does not see at all, nor does it possess eyes which are plainly visible, but, when the skin is removed, the places for the eyes are seen, and the "irises" occupy the exact positions naturally belonging to the eyes, as seen from outside, the appearance being just as if the eyes had been injured during their development, and the skin had grown over them.‡

In many other passages Aristotle refers to the blindness of the *Aspalax*. This was probably the common mole (*Talpa europea*), but some have tried to identify it with the so-called blind mole (*T. cæca*), which Dobson describes as a distinct species, characterized chiefly by the presence of membranes over its eyes,§ while Camerano considers it to be merely a variety of the common mole.‖

Whichever view is correct, it is certain that skins of the so-called blind moles are not readily distinguishable from those of the common moles, and Mr. Oldfield Thomas has assured me that not all blind moles have membranes over their eyes.

When Aristotle refers to the covering of the eyes of *Aspalax*, he uses the word *derma*, which refers particularly to the skin of the body, and, in *H. A.* iv. c. 8, s. 2, he calls it the thick skin enveloping the animal's head. There is no suggestion that he refers to membranes covering the eyes.

* *De Anima*, ii. c. 7, 419*a*; *De Sensu, &c.*, c. 3, 440*a*.
† *De Sensu, &c.*, c. 2, 438*a*. ‡ *H. A.* i. c. 8, s. 3.
§ *Monogr. of the Insectivora*, Part 2, 1883, p. 139.
‖ *Mem. della Reale Accad. delle Sci. di Torino*, 2nd series, vol. 37, 1886, pp. 445, 446.

This being so, it seems that the common mole, with its small, jet-black eyes, in which no iris or sclerotic can be seen, furnishes the best identification of the *Aspalax*. The fact that its eyes can be seen through very small holes in its skin, when the hairs surrounding them have been blown aside, probably escaped Aristotle's notice.

In connection with his statement about the eyes of *Aspalax* being, as it were, injured during their development, it may be stated that Mr. R. J. Lee says that the mole has, at birth, eyes of a considerable degree of perfection, showing an iris, white sclerotic, lens, and optic nerve, but that, as the animal grows, it is deprived of the means of sight in consequence of certain changes at the base of the skull.*

From very early times, a belief in the total blindness of the mole has been very persistent. Æsop, Aristotle, Cicero, Virgil, Seneca, Pliny, Oppian of Syria, and several other ancient authors refer to its blindness. Galen, however, believed that the mole had a feeble sight. At a much later time, Gesner, apparently following Albertus, says that there is nothing wonderful in the mole being without eyes, for it hunts worms in the earth, where eyes would be useless, and yet it perceives, in some way, whether it is below or above ground.† Aldrovandi says:—"I shall follow Scaliger's opinion, who attributes very weak sight to the moles, . . . not in order to see under ground, but only to avoid the light."‡ Finally, Owen asserted that, in the common mole and especially in the blind mole, the eye is reduced to its simple primitive office of taking cognizance of light, a filament of the fifth nerve aiding a remnant of a proper optic nerve.§

A belief in the total blindness of the mole is not uncommon in this country, and Mr. G. C. Zervos, writing from Calymnos, informs me that modern Greeks consider the mole to be blind.

All classes of animals, Aristotle says, except his *Ostrakoderma* and some other animals without blood, have eyes.‖ He says, however, that solens try to escape downwards, when they see anything pushed towards them, and that pectens close their shells when anyone thrusts a finger near them, just as if they could see.¶ In many passages he mentions the eyes

* *Proc. Roy. Soc.*, vol. 18, 1870, pp. 326, 327.
† *Hist. Anim.* i. 1551, p. 1056.
‡ *De Quadr. Digitat. Viviparis, &c.*, 1637, p. 452.
§ *Anat. Vertebr.* vol. iii. 1868, p. 246.
‖ *H. A.* i. c. 8, s. 3. ¶ *Ibid.* iv. c. 8, s. 18.

of cephalopods, crustaceans, and his *Entoma*, and he evidently suspected the existence of visual organs in solens and pectens.

Respecting the sense organs in general, it may be said that there are many passages difficult to understand, and sometimes inconsistent, in Aristotle's works. A discussion of one series of such passages will conclude this chapter.

He says that philosophers of his time tried to assign to each sense organ one, and only one, of the *elements*, but that, since there are five senses they found some difficulty in assigning the four elements to them.* He does not seem to adopt this view of the sense organs, but in many passages of his works he attempts to assign one or more of the sense organs to certain *elements*. In *De Sensu*, &c., c. 2, 438*b*, *e. g.*, he assigns vision to *water*, hearing to *air*, and smell to *fire*, and, in *De Anima*, iii. c. 1, 425*a*, he assigns vision and hearing to *water* and *air*, respectively, smell to either, and suggests that all the senses may be assigned to *fire*, and touch to *earth*. The chief sensory organ of touch being, according to Aristotle, the heart or region of the heart, which is the centre of heat, this attempt, in *De Anima*, iii. c. 1, 425*a*, to assign the senses to the elements is difficult to understand. Some commentators consider the passage cited above from the *De Anima* to be corrupt.

* *De Sensu, &c.*, c. 2, 437*a*.

CHAPTER XIII.

ANIMAL MOTION.

Numerous passages relating to animal motion are to be found in several of Aristotle's works, especially his *Progressive Motion of Animals*, *History of Animals*, and *Parts of Animals*. In these passages, many of which are mere repetitions, he gives interesting information about the locomotory parts and their movements, in walking, creeping, flying, and swimming. His views on the causes of these movements are, however, very incompletely expressed.

According to him, every animal with feet has an even number of these, and fishes either have no fins at all or two or four fins, for he takes no account of fins other than the pectoral and pelvic.*

The number four seems to have had a special significance in connection with his ideas about animals. He says that they are moved by four or more σημεῖα, those with blood by four only, and those without blood by more than four.† It was sufficient, in fact, to count the σημεῖα, whether fins or other paired means of locomotion, to decide whether an animal had or had not blood, *e. g.*, speaking of fishes, he says that they cannot have more than four fins, for if they had they would necessarily be animals without blood.‡

The word σημεῖον (semeion), which means a sign or token by which anything is known, is used in a special sense by Aristotle to indicate the organs or means by the aid of which animals moved from place to place. According to him, legs, arms, wings, paired fins, and even the bendings of the body of a grass-snake, eel, or caterpillar, when in progressive motion, were semeia.

Referring to the way in which they move, he says that animals, whether they have four or more feet, move in the same way, for their feet move in diagonal succession, but

* *H. A.* i. c. 5, ss. 1 and 2.
† *H. A.* i. c. 5, ss. 6 and 7; *De Anim. Incessu*, c. 10.
‡ *P. A.* iv. c. 13, 696*a*.

the lion and both camels, Arabian and Bactrian, amble so that the right foot does not go in front of the left, but follows it.* The phrase used by him to denote movement in diagonal succession is κατὰ διάμετρον (kata diametron), and is fully explained in his *De Anim. Incessu*, c. 14, where he says that the left hind limb is moved after the right front limb, then the left front limb, and, finally, the right hind limb. The camel ambles by moving the right feet and the left feet alternately, the right front and hind feet striking the ground simultaneously, or nearly so, and then the left feet. The peculiarly unpleasant feeling experienced when riding a camel is due to this mode of progression. In the giraffe also the amble is particularly well seen, and it is sometimes seen in the horse, lion, and many other animals. The statement that the right foot does not go before the left, but follows it, is not clear. Pliny's translation, in *Nat. Hist.*, xi. 105, makes the left foot follow the right, and has been adopted by many commentators. Considering the nature of the amble, neither the right nor the left limbs can be properly said to follow the others. There is not sufficient reason for assuming that the Greek text has been tampered with, but it seems to be intended to distinguish between progression κατὰ διάμετρον, in which the traces of the right feet often cross those of the left, and the amble, called by Aristotle κατὰ σκέλος, or leg by leg, in which the right pair of limbs and the left pair of limbs swing past each other without crossing.

Aristotle knew that some relationship existed between the arms of Man, the forelegs of quadrupeds, the wings of birds, and the pectoral fins of fishes, which are known to be homologous. His views on this relationship will be considered further in Chapter xv.

Among the numerous statements made by him about the locomotory parts and the movements of progression of particular animals or groups of animals, the most important are those relating to the elephant, camel, birds, fishes, cephalopods, and crustaceans. Some of these statements will be discussed next.

Aristotle says: "Animals have the joints of their limbs, anterior and posterior, turned oppositely to one another, and, with the exception of the elephant, oppositely to those of Man, for, in viviparous quadrupeds, except the elephant, the front legs are bent forwards and the hind legs back-

* *H. A.* i. c. 5, s. 7, ii. c. 1, s. 8.

wards, and therefore they have the hollows of their joints turned towards each other. The elephant is not formed in the way some have said, but sits down and bends its legs, only it cannot bend them on both sides simultaneously, because of its weight, but sinks down on its right or left side, and sleeps in this position. The elephant bends its hind legs, just like Man."*

Aristotle's comparison between the limbs of Man and the elephant and those of other animals was based on an examination of their external appearance. Viewed in this way, the real structure of their limbs may be easily misunderstood. The elephant has long femoral and humeral bones, very highly inclined, and its knee-joints consequently come low down and are not hidden in any way. Its limbs are, therefore, more easily comparable with those of Man, and the similarity is seen at once. On the other hand, the comparatively short length and usually small inclination of the femoral and humeral bones of the horse and many other animals cause the knee-joints to come close to the body, and even to be partly hidden within its skin, while the joints between the radius and tibia and the corresponding cannon bones are very conspicuous, and may be easily taken for the knee-joints.

Although Aristotle says, in the passage cited above, that elephants bend their legs and sit or lie down, he asserts, in *P. A.* ii. c. 16, 659*a*, that their forelegs are mere supports and are useless for anything else, because of their slowness and small adaptability for bending. He distinctly states elsewhere that the old opinion about the elephant having no joints in its legs is not true, and that this animal walks in consequence of a bending at the hips and shoulders.† Evidently he was not altogether free from the old opinion which, strange to say, persisted until comparatively recent times.

According to Aristotle, the elephant cannot swim, but, when crossing rivers, walks through the water as long as the tip of its trunk is above it.‡ This is not quite correct. The elephant can swim, and does so with probably less relative immersion than other quadrupeds. Sir J. Emerson Tennent says, however, that an elephant "generally prefers to sink till no part of his huge body is visible, except the tip of his trunk, through which he breathes, moving beneath the

* *H. A.* ii. c. 1, s. 4. † *De Anim. Incessu*, c. 9.
‡ *H. A.* ix. c. 33.

surface, and only now and then raising his head to look that he is keeping the proper direction."*

The camel, Aristotle says, has one knee in each leg and not more, as some say, but it seems to have more because its abdomen is girded or drawn up.† Aristotle seems to be referring to a passage in Herodotus (iii. 103), where it is stated that the camel has four knees in its hind legs. The apparent presence of more than one knee in each leg is due partly to the great length and high inclination of the femoral bones, and partly to the great length of the cannon bones, thus causing the knee and tarsal joints to be very conspicuous. Aristotle does not appear to have been deceived by these structural features; he states distinctly that there is only one knee in each leg. The phrase rendered by the words "because its abdomen is girded or drawn up" is, in Schneider's Greek text, *διὰ τὴν ὑπόστασιν τῆς κοιλίας*, and this agrees with the texts of the Royal Prussian Academy, Camus, Syllburg, and Aldus Manutius. The word *ὑπόστασις* primarily means a sediment, and also a prop or support. Several commentators, having concluded that the word does not express Aristotle's meaning very well, have proposed alterations of the text, and both Schneider and Wiegmann were in favour of substituting *ὑπόσταλσις*, a tightening up or contraction. The word *ὑπόστασις* is used in an obscure sense, but the meaning of the passage is clear, and is forcibly brought to the mind of anyone who looks at a living camel, with its tightly drawn up abdomen and long legs.

The difficulties of the passage just discussed are small compared with those of the first part of the one in which Aristotle attempts to describe the structure of the cloven foot of a camel. This passage, in *H. A.* ii. c. 2, s. 6, presents such difficulties that, in their interpretation of it, scarcely any two translators agree. Part of the passage is as follows:—*ἐκ μὲν τοῦ ὄπισθεν μικρὸν ἔσχισται μέχρι τῆς δευτέρας καμπῆς τῶν δακτύλων, τὸ δ' ἔμπροσθεν ἔσχισται μικρὸν ὅσον ἄχρι τῆς πρώτης καμπῆς τῶν δακτύλων ἐπ' ἄκρῳ τέτταρα* ("from the back it is divided a little as far as the second joint of the toes, but the front is divided a little just about as far as the first joint of the toes, four at the tip"). Even with respect to essential parts of the passage very different views have been expressed. Camus and J. Barthélemy Saint-Hilaire consider that it refers to divisions of the hind and front parts of the foot, Schneider

* *Nat. Hist. of Ceylon*, 1861, p. 121. † *H. A.* ii. c. 2, s. 5.

and Wiegmann prefer to believe that it refers to the divisions of the hind and front feet, and Sundevall despairingly asserts that the passage is inexplicable.

The front feet of a living camel are decidedly larger than the hind feet, and there are some minor differences of form, but both are divided similarly. The back part of each foot is curved inwards a little, but is not cleft. It is probable, therefore, that Aristotle is describing the front parts of a camel's foot, and this is assumed in what follows.

When the upper part of a camel's foot is compared with its sole, it is seen that the length of the parting between the toes, seen from above, is not less than twice that of the parting, as seen from below. The difference is due to the presence of the web, to which also Aristotle refers. Further, looking more closely upon the top of the foot, four parts of the cleft are seen, two on each side, caused by the prominence of the proximal phalanges, and especially of their distal ends; this is better seen in some camels than in others. Making use of these features in interpreting Aristotle's description, it is probable that the words ὄπισθεν and ἔμπροσθεν respectively refer to the sole and the upper part of the foot, and the phrase ἐπ' ἄκρῳ τέτταρα to the two short parts of the toes, as seen on the sole, together with the two long parts, as seen from above. It is possible, but less likely, that the passage refers to the features of the cleft due to the aforesaid prominence of the proximal phalanges.

The rest of Aristotle's description of the structure of the feet of camels presents no important difficulty, and the sense of the entire description seems to be as follows: "The sole of the foot is cleft as far as the second joint of the toes, and the upper part is cleft about as far as the first joint, there being four parts at the front of the foot, and between the cleft parts is a web, as in geese. The lower part of the foot is fleshy, like the foot of the bear, and, therefore, during warlike operations, riders put coverings on their camel's feet, when these are sore."*

Aristotle makes some interesting observations on the flight of birds and their so-called tail. He says that all birds which fly high have four toes,† that birds are without a tail but have an *orrhopygion*, the long-legged and the web-footed birds having a short one and the others a long

* *H. A.* ii. c. 2, s. 6. † *Ibid.* ii. c. 8, s. 2.

one, and that these hold their feet close to their bodies, during flight, while the long-legged and web-footed birds keep them stretched out.*

Most of these statements are subject to some exceptions. Among birds which Aristotle probably knew some have only three toes, yet they often fly high, *e. g.*, bustards and golden and some other plovers. Again, the sparrow-hawk, gos-hawk, and harrier, among long-legged birds, and the tern and male pintail-duck, among web-footed birds, have comparatively long tails. Among birds with which Aristotle was probably not acquainted, there are still more striking exceptions, *e. g.*, the secretary-vulture, the Brazilian seriema, the Tropic bird, and Buffon's skua. Further, I have observed that, when in full flight, pigeons, pheasants, black game, and many other birds, which have long or large tails as well as comparatively short legs, carry their feet stretched out backwards, and that some long-legged birds, such as the redshank and storm petrel, often hold their feet downwards.†

It will be noticed that Aristotle gives to the so-called tail of a bird a special name, *orrhopygion*, which still survives in the modern anatomical name *uropygium*. He was not the first to use the word, for Aristophanes had applied it to the abdominal extremity of a gnat,‡ and of a wasp.§

On account of his idea that an animal with blood could not have more than four means of progression, he neglected all fins except the pectoral and pelvic, and accordingly he says that the gilt-head and bass have four, the eel and conger two, and the muræna none at all.‖ He misunderstood the nature of the fins of some cartilaginous fishes, *e.g.*, the skate and sting ray, for he considered the large pectoral fins of these fishes to be lateral expansions or "flat parts," for use in swimming.¶

The cephalopods, he says, swim backwards rapidly by means of their arms and fins, and the crustaceans by means of the hinder parts of their bodies.** He does not seem to take account of the importance of the jets of water expelled through the funnel, in the cephalopods, by means of which these animals propel themselves backwards. He states,

* *H. A.* ii. c. 8, s. 4.

† Lists of birds which carry their feet backwards and of some which carry them forwards are given in *The Zoologist*, 1903, pp. 146–9.

‡ *The Clouds*, 158. § *The Wasps*, 1075.

‖ *H. A.* i. c. 5, s. 2. ¶ *Ibid.* ** *Ibid.* i. c. 5, s. 3.

however, in *H. A.* iv. c. 1, s. 6, that the octopus emits its ink and also sea-water through its funnel.

He was aware that most of his *Ostrakoderma* move but slowly or are stationary, and that the pecten (*Kteis*) "flies" some distance along the surface of the water by its own efforts, and says that it is more capable of locomotion than any other.* He also says that the sea-urchin travels by using its spines as feet.†

It has been stated already that Aristotle did not understand the nature of nerves, some of which he probably saw. It is interesting, therefore, to inquire by what means he considered the various locomotory and other movements of the body to be effected. Nowhere does he make this clear. He says that the heart is the centre of motion, that it is accordingly full of tendons, and that the motions of which it is the centre are effected by contraction and relaxation.‡ How the motions are transmitted from the heart to the moving parts he does not explain, but he often mentions the sinewy nature of the aorta, and especially its small branches, and, in *H. A.* iii. c. 6, he says that the *fibres* are intermediate between sinew and blood-vessel. He says, however, that there is a want of continuity in the arrangement of the sinews,§ and this may be the reason why he abstained from attempting to explain the mechanism of animal motion, although he wrote a great deal about the motions themselves. An important passage on this subject is in the *De Anim. Motione*, c. 7, 701, one of the Aristotelian treatises which was probably not written by Aristotle himself. In that passage it is stated that animals are moved by means of bones and sinews, the bones being like the wooden and iron frames of automata, and the sinews like cords by which the frames are set in motion. It is also stated that the parts of automata do not change in form and size, like the parts of an animal, in which this change is caused by heat and cold, which respectively effect expansion and relaxation under the influence of imagination, sensibility, and thought.

* *H. A.* ix. c. 25, s. 7.
† *Ibid.* iv. c. 5, s. 6.
‡ *P. A.* ii. c. 1, 647*a*, iii. c. 4, 666*b*.
§ *H. A.* iii. c. 5, s. 1.

CHAPTER XIV.

GENERATION AND DEVELOPMENT.

Most of the important researches made by Aristotle on generation and development are described in his *Generation of Animals*, one of the most remarkable works ever written, and the one most entitling him to be included amongst the greatest thinkers of all time. Even those who have minimized the value of his labours and have criticized his works adversely have often been forced to comment favourably on many parts of his *Generation of Animals*. His *History of Animals*, which rivals his *Generation of Animals* in greatness, is remarkable for the vast amount of information which it contains, but the *Generation of Animals* astonishes the reader by its deep, philosophical reasoning, and furnishes evidence of a powerful intellect grappling with obscure embryological problems.

In his *Generation of Animals*, he proposes some abstruse questions, and attempts to solve them in a way which is masterly, considering the slender means of investigation at his disposal. Some of these questions had been considered before his time, but not efficiently. Aristotle also did a great deal of original work (considered already in Chapter xi.) on the generative organs; nothing, he says, had been previously determined about these.*

He discusses an opinion, held by some philosophers and based mainly on the observed similarity between young animals and their parents, that the sperm (σπέρμα) was derived from all parts of the body.† He rejects this opinion, and, in *G. A.* i. c. 18, adduces arguments against it, of which the following are the most important:—

(1) Children have nails, hair, &c., no part of which could, he believed, be derived from the parents.

(2) Children often resemble grand-parents or other ancestors, from whom he believed they could not derive anything, *e.g.*, a daughter of an Æthiopian and a woman of Elis was not black, but the son of this daughter was.

* *G. A.* i. c. 1, 715*a*. † *Ibid.* i. c. 17, 721*b*

(3) From butterflies and some other animals, *skolekes* or larvæ are produced, and these are not like the parents.

(4) Animals which are not deformed may be generated by deformed parents.

For reasons such as these he concluded that the sperm was not derived from all parts of the parents. He says that it is more fitting that it should be produced from homœomeria, these being anterior to and forming the anhomœomeria.* Proceeding then to a more definite conclusion, he says that the sperm is a part of the superfluous matter of the blood, or something analogous to it.† He does not, however, clearly express his views about the nature of this superfluous matter and its mode of separation, but his meaning, expressed chiefly in *G. A.* i. c. 19, 726*b*, seems to be that, after some parts of the blood have been disposed of as nutritive or formative material for the flesh and other parts of the body, there remain a part which is the last to be supplied to the parts of the body and a residual or superfluous part, which is of a very useful nature and has great power (δύναμις). This constitutes the sperm, and since it is like the part, referred to above, which is the last to be supplied to the parts of the body, it is reasonable that it should be capable of forming parts similar to these, *i.e.*, similar to the parts of the parents. The sperm, in fact, has potentially in itself each of the parts of the body. It will be noticed that this view bears some resemblance to the evolution theory elaborated by Bonnet and others, but differs therefrom in the way in which the parts were supposed to exist in the sperm, for, according to the evolution theory, the parts actually existed in miniature in the sperm.

Aristotle also discusses, at great length, the nature of the material, if any, contributed by the male and the female. He concludes that the female contributes the material of the embryo, and that such material is derived from the catamenia. He seems to have believed that the material contributed by the female was passive formative material.‡ The essential generative agency, he believed, was contributed by the male, but it was not necessary for anything material to pass from the male to the embryo, for the male contributed not matter but form and motive principle.§ So fully did he believe this that he seems to have had no misgiving about

* *G. A.* i. c. 18, 722*a*.
† *Ibid.* i. c. 18, 725*a* and 726*a*.
‡ *Ibid.* i. c. 20, 729*a*.
§ *Ibid.* i. c. 20, 729*a*, i. c. 21, 729*b*.

the possibility of hen partridges being impregnated by the breath of the cock.* This was an old popular belief.

In *G. A.* i. c. 21, 729*b*, he illustrates his views by saying that what the female contributes to the embryo is like the wood which is formed into a couch by the carpenter's art, or like the material of a sphere of wax, the form due to the art of the carpenter, in one case, or of the modeller, in the other, being comparable with the influence contributed by the male.

Aristotle's reasoning on these questions is philosophical and powerful, but without the aid of the microscope such questions could not be solved satisfactorily. The ova contributed by the female are now known to be exceedingly complex in structure, and not to be composed of merely passive formative material. Again, considering the nature of the catamenia and the fact that, in *H. A.* vii. c. 2, and in other passages, he shows that he understood the purifying nature of them, it is difficult to understand why he should have considered them to represent, in the female, the sperm of the male. There seems to be no doubt about this opinion, and he attempts to explain that the catamenial fluid is a sperm which has not been fully elaborated.†

It is well known by embryologists that, until the researches of Weissmann and others, the theory of epigenesis was generally held to be true. This theory was foreshadowed by Aristotle, and elaborated by Harvey, Wolff, and Blumenbach. According to this theory, the parts of the young animal are developed as new formations in the embryo, and, in contradistinction to the old evolution theory, do not exist as pre-formed parts in miniature, either in the spermatozoon or in the ovum. Aristotle's views are set out, in *G. A.* ii. c. 1, in such a way as to show that he was not quite free from a belief in the existence of pre-formed parts. He seems to have believed that the germ contained some kind of vital principle, and was so constituted that, the vital principle having started the process of development, this process went on, like an automaton, the parts of the young animal being produced one after another, in the way suggested in the so-called verses of Orpheus, in which it is stated that the parts are formed in succession, like the knots of a net. The heart, having in itself a source of increase, was generated first, according to Aristotle, and then other

* *H. A.* vi. c. 2, s. 9. † *G. A.* iv. c. 5, 774*a*.

parts, such as, for example, the liver, lungs, and eyes, were produced from it, just as a man is produced from a child, but not by the child.

Further, he says that the young animal is not at once a horse or a man, but that its life is at first like that of a plant, and that the characteristics of each kind of animal are the last to be developed.* This seems to foreshadow the modern theory that the history of the development of the individual is an epitome of the history of the evolution of the species.

A most difficult question in embryology is that dealing with the causes determining the sex of the young animal. This question was discussed before Aristotle's time, and has been discussed until the present day. Anaxagoras believed that the distinction depended on the position of the sperm itself in the uterus, Empedocles that it depended on the temperature of the uterus, a hotter uterus bringing forth a male and a colder one a female, and Democritus believed that the distinction depended on the preponderance, in some way, of one or other of the sperms, male and female. Aristotle was inclined to adopt a view similar to that of Democritus, and seemed to regard the action between the sperms to be of the nature of a contest, the sex of the young animal corresponding with that of the sperm which overpowered the other.† As late as the year 1898, a theory of this kind was set forth by Dr. Leopold Schenk, of Vienna.‡ Generally speaking, this theory was the opposite of Aristotle's, for Schenk's view was that the tendency was for offspring to take the sex opposite to that of the more vigorous parent.

Aristotle's statements about spontaneous generation have been discussed in Chapter v. It was easy for the Ancients to persuade themselves that spontaneous generation commonly occurred, for they had no means of knowing that, in matter believed by them to be lifeless, there existed countless germs giving rise to numerous forms of life. Some even believed that the spontaneous generation of mankind was possible. Aristotle's views were less extravagant, but he believed that eels, many of his *Entoma*,§ and most of his *Ostrakoderma*,‖ were generated spontaneously. He says that eels had never been found with milt or roe, that, when opened, they did not seem to possess generative organs, and

* *G. A.* ii. c. 3, 736*b*. † *G. A.* iv. c. 1.
‡ *Schenk's Theory: The Determination of Sex*, London, 1898.
§ *H. A.* v. c. 17, s. 2. ‖ *H. A.* v. c. 13; *G. A.* iii. c. 11, 761*b*.

that they seemed to be produced from the so-called *entrails of the earth*, apparently referring to certain worms formed spontaneously in mud and the like.*

The mode of reproduction of eels was in question for many centuries, and although it had been known for some years that there was a clear distinction of sexes among eels, and that they passed from the rivers to the sea for breeding purposes, it was not until about the year 1896 that the mode of reproduction and development was fully ascertained. At that time, Prof. Grassi and Dr. Calandruccio ascertained that a fish, previously considered to be a distinct species, *Leptocephalus brevirostris*, was a larval form of the common eel. This larval form, which is flat and transparent and has a very small head, passes through a series of metamorphoses into the *elver* or young eel. The *elvers* swim up the rivers in spring. Millions of them swim up the Severn, and have long been believed by people in Gloucestershire to be young eels.

The egg-cases of whelks and other molluscs were known to Aristotle,† but he was not disposed to believe that these animals were generated otherwise than spontaneously.

The metamorphoses of some of his *Entoma* received much attention from Aristotle. According to him, all his *Entoma* produce *skolekes*,‡ or all, except certain Lepidoptera, which produce seed-like bodies containing fluid.§ The passages relating to his *skolekes* are too numerous to be given in full, but an epitome of the most important follows, so far as the difficult nature of the subject permits.

He appears to have been aware of the existence of the ova or eggs of some of his *Entoma*, especially certain butterflies and moths, locusts and spiders,‖ but considered them to be, not eggs, but egg-like *skolekes*. The ova of many *Entoma* escaped his notice, but he was aware of the existence of their *skolekes*, and believed that these were the first products of generation.¶ The *skolekes* fed, grew rapidly, and underwent changes, more or less complex, until they passed into the pupa or chrysalis form.**

The *skolekes* of the various kinds of *Entoma* are not treated by Aristotle in the same way. When dealing with those of bees, wasps, and the like, the larvæ are called

* *H. A.* vi. c. 15. † *Ibid.* v. c. 13.
‡ *G. A.* ii. c. 1, 733*a*. § *H. A.* v. c. 17, s. 1.
‖ *Ibid.* v. c. 17, ss. 1 and 4, v. c. 23; *G. A.* iii. c. 9, 758*b*.
¶ *G. A.* ii. c. 1, 733*b*. ** *H. A.* v. c. 17, ss. 4–6.

skolekes right up to the pupa stage; * on the other hand, the *skolekes* of butterflies and moths are said to become *kampai*, or caterpillars, before they become pupæ.† The apparently great difference between the caterpillars of butterflies and moths, and the maggots of bees, wasps, and flies, was probably the cause of this difference of treatment, but he considered both caterpillars and maggots to be *skolekes*, finally passing into the "real eggs," or pupæ.

His views on this subject are set forth in fairly clear language. He states that *Entoma* bring forth *skolekes* at first, but these become egg-like in the course of their development, for the so-called chrysalis is functionally equivalent to an egg.‡ He also says: "For we must consider caterpillars to be a kind of *skolex*, and also the [generative products] of spiders, and yet it may seem that some of these and many others resemble eggs, because of their roundness, but they should not be defined by their form, nor their hardness and softness, but by their producing an animal as the result of a change of the whole and not a part. When they have completely attained the *skolex* form, and have become of full size, they are, as it were, eggs, for the skin hardens about them, and they become motionless at this time. This is evident in the *skolekes* of bees and wasps and in caterpillars. The reason for it is that, because of the imperfect nature of the animals, their 'eggs' are produced, as it were, before their time, the *skolex* being, as it were, an egg which is still soft and in process of growth." §

This is the most important passage on the *skolex* in all Aristotle's works. It shows clearly, in conjunction with the other passages cited, that his *skolex* is an immature product of generation, which grows and finally becomes a pupa, or, so Aristotle believed, an "egg," giving birth to the perfect animal. It differed from the egg of a bird, which has a hard shell and does not grow, the young bird being formed from a part only of the egg, the remainder serving as food.‖

His discussion of the generation of bees is particularly interesting. He refers to the many different opinions which had been given on the subject, and says that much uncertainty existed about the mode of generation of bees. He

* *H. A.* v. c. 17, s. 5, v. c. 20, s. 1.
† *Ibid.* v. c. 17, ss. 4 and 6.
‡ *G. A.* ii. c. 1, 733*b*.
§ *Ibid.* iii. c. 9, 758*b*.
‖ *H. A.* i. c. 4, s. 1.

seems to think that a kind of hermaphroditism occurs among the workers, and finally decides that the rulers or kings (queens) generate both themselves and the workers, that these generate the drones, and that these generate nothing, but are idle, while the queens remain in the hives free from all unnecessary labour.*

It is now known that the queen of a hive generates queens, workers, and drones, the workers being normally barren females, and the drones males; parthenogenesis sometimes occurs. The production of a queen from a fertilized egg depends on the supply of a superior quality of food, called "royal jelly," to the hatched-out larva, and this feeding is arranged by those bees which act as nurses. It is sufficient for the queen to be impregnated once only by a drone, for the purpose of depositing vast numbers of fertilized eggs.

Aristotle very clearly suggested the possibility of hermaphroditism, and was inclined to believe that it was found in some fishes. He says that if there exists a class of animals which includes females but not separate males, then it is likely that such animals generate from themselves, and that, although up till his time such a question had not been investigated sufficiently to justify a belief, there was some probability that hermaphroditism occurred among some fishes. No males had been seen, he adds, among the *Erythrinoi*, but the females were full of embryos; he had not, he says, found out anything very trustworthy about this.† It seems that he also believed that the fishes called by him *Psetta* and *Channe* were hermaphrodite.‡

The researches of Cavolini, Cuvier, and others have proved that hermaphroditism occurs regularly in *Serranus scriba*, *S. cabrilla*, and other species of *Serranus*, and that it occurs in some perches, carp, mackerel, herrings, soles, whiting, and other fishes. Aristotle's *Erythrinos*, *Channe*, and *Psetta* have not been satisfactorily identified, but Cuvier believed that *Erythrinos* was *S. scriba* and *Channe* was *S. cabrilla*.§

A remarkable discovery of modern times is the common occurrence, in *Aphis*, *Cypris*, and many other forms of life which multiply with very great rapidity, of parthenogenetic

* *G. A.* iii. c. 10, 759*b* and 760*a*.
† *Ibid.* ii. c. 5, 741*a*.
‡ *H. A.* iv. c. 11, s. 4, vi. c. 12, s. 1.
§ Cuvier and Valenciennes, *Hist. Nat. des Poissons*, Paris, 1828–49, vol. vi. pp. 179–80.

females. Aristotle says nothing about such a phenomenon in animals such as those mentioned, but, strange to say, he seems to have believed in the occurrence of a kind of parthenogenesis in mice, for he says that, in some part of Persia, pregnant females are found in the uterus.* This seems to have been a version of a folk-tale to account for the reports current among the Ancients about the amazing rate of increase in the numbers of mice.

The embryonic development of young animals is discussed chiefly in *G. A.* ii. c. 6, on animals in general, and in *H. A.* vi. c. 3, on birds. Aristotle also commences *H. A.* vii. with the intention of describing the development of Man, from the earliest stages of the embryo to old age, but that book is incomplete and contains very little about the subject of development. The so-called Tenth Book of Aristotle's *H. A.* was believed to be a continuation of Book vii., but it is now admitted that Aristotle did not write it, and, further, on the subject of development it contains nothing of interest.

The following is a statement of what appear to have been Aristotle's views, as set out in *G. A.* ii. c. 6, on embryonic development:—The upper or anterior parts of the body are generated first, and, except in the *Entoma*, are proportionally larger than the other parts, the head and eyes being especially large. The larger organs may be seen before the smaller ones, although not necessarily developed before them. In animals with blood, the heart is produced first and blood-vessels extend from it. Then, in order to moderate the heat of the heart, the brain is next formed and also the other parts of the head. The purest parts of the blood pass from the blood-vessels, like water oozing through vessels of partially baked earthenware, and cause the formation of flesh and the main parts of the sense organs. The skin of the body is formed by the drying of the superficial parts of the flesh. From the less pure or more earthy parts of the blood are formed the more earthy parts of the body, *e. g.*, bones, sinews, nails, horns, hoofs, and hair, which are the later formed parts. All the bones are formed in the fœtus, and no bones are produced later. About the formation of the eyes there is some uncertainty, he says, but their development is completed at a very late stage. The formation of the bones and sinews is due to the

* *H. A.* vi. c. 30, s. 3.

abstraction of moisture from the less pure parts of the blood, by means of the internal heat.

Many of these views are incorrect, but they are evidently based on actual dissection or inspection of embryos in one or more animals. It will be sufficient, however, to state that the cerebro-spinal axis is one of the first parts to be laid down, and that the parts of the body are not developed in succession in the way Aristotle seems to have believed. Many parts, *e. g.*, the flesh, bones (first laid down as cartilages), sinews, skin, sensory organs, heart, alimentary canal, and liver, are in process of development simultaneously. He knew nothing about the formation of membrane bones or the process of ossification of cartilages. It is quite true that, as Aristotle says, the eyes are completed at a late stage of embryonic development.

His most interesting embryological research is that on the development of a chicken. This research alone entitles him to considerable credit as an original investigator. It is difficult to follow some parts of his description, in *H. A.* vi. c. 3, not only because of apparent defects in the Greek text, but also because Aristotle gives only a few definite statements about the times of incubation at which the appearances to which he refers were seen.

One question on which Aristotle's opinion would be of interest relates to the position of the part of the egg in which development begins. His statements on this question are not as clear as could be wished, but it seems that he believed that the part referred to was in the pointed end of the egg. In a passage, the full meaning of which is not clear, he speaks of a movement of the yolk or a part of it towards the pointed end (ὀξύ) of the egg, where, he says, is the beginning (ἀρχή) of the egg.*

He seems to have been misled by assuming that an egg issues from the parent in a manner different from the way in which a young mammal comes to light, for he says that the foot end, as it were, of the egg issues first, whereas the head or beginning (ἀρχή) of a young viviparous quadruped first comes to light.† He knew also that the broad end of the egg leads during the process of laying.‡ It was natural, therefore, for him to conclude that the pointed end was the beginning of the egg. His error will not appear to be extravagant if it is borne in mind that Hieron. Fabricius

* *H. A.* vi. c. 3, s. 1.
† *G. A.* iii. c. 2, 752*b*.
‡ *H. A.* vi. c. 2, s. 2 *G. A.* iii. c. 2, 752*a*.

believed that the germ spot or disc (*cicatricula*) was only a trace of the attachment of the yolk to the ovary, and that the chalazæ constituted the material of the embryo, being the main cause of embryonic development (*præcipua causa pulli generationis*) after having been impregnated,* and that Harvey seems to have believed that embryonic development began in the broad end of the egg.†

Even to-day, many people believe that the chalazæ are what they call the "life" of the egg, and this represents to their minds the parts where development begins.

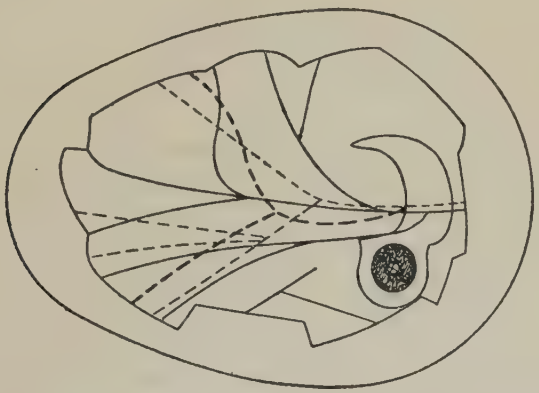
Aristotle says that the first signs of development are noticeable after three days and nights, the heart being visible as a palpitating blood-spot whence, as it develops, two blood-vessels, which wind about, extend to the surrounding tunics, and a membrane with threads of blood encloses the whole, away from the aforesaid blood-vessels. A little later, he continues, the body of the embryo, quite small and white, is seen, the head being distinct and the eyes very prominent or conspicuous, while the lower parts of the embryo are not in proportion to the upper parts. One vessel from the heart leads to the enveloping membrane and the other to the yolk, after the manner of an umbilical cord. The development of the young bird, he says, commences from the white, and its nutriment is derived from the yolk, through what is equivalent to an umbilical cord.‡

Such is Aristotle's description of the development of a chick, from about the fourth day to about the eighth day, judging from the appearances he describes. It is now known that development of the embryo commences in the germinal spot or disc, situated on one side of the yolk. In consequence of the yolk opposite the germinal spot being denser than that on the side of the spot, this remains uppermost, however the egg may be rotated by the sitting hen, the yolk being steadied by the chalazæ. During the early stages of development, the embryo is in process of being constricted off from the yolk, and a bulging is noticeable, although, on account of an apparent sinking in of the embryo, the bulging is only slight. The time at which signs of development are first seen by the unaided eye depends not only on the acuteness of vision of the observer, but also on the extent of his knowledge of embryology, but it may be said that signs may be

* *De Formatione Ovi et Pulli*, Padua, 1625, pp. 24, 34, and 48.
† *Exercitat. de Gener. Anim.*, 1680, p. 64.
‡ *H. A.* vi. c. 3, ss. 1–3.

seen on the second day, or about twenty-four hours earlier than Aristotle states. About the end of the second day, the rudimentary heart with the vitelline blood-vessels extending over the yolk sac are visible, and, on the third day, they

FIG. 9.



EGG OPENED AFTER EIGHT DAYS' INCUBATION.

——— Allantoic Blood-vessels.

– – – – – Vitelline Blood-vessels.

FIG. 10.

CHICK REMOVED FROM EGG AFTER TEN DAYS' INCUBATION.

become conspicuous. By this time the embryo is raised from the underlying substance of the yolk, being connected therewith merely by a short stalk. During the fourth day, the enclosure of the embryo by the coalescence of the head and tail folds of the amnion becomes complete. On the fifth

day, the wings and legs are just recognizable as outgrowths, and the allantois, an embryonic sac destined to serve as a respiratory organ beneath the shell, begins to grow rapidly; on the sixth day, the allantoic blood-vessels are clearly seen as well as the vitelline blood-vessels, while the embryo has greatly increased in size. The appearance is much the same on the seventh day, but the embryo is still larger, and the same may be said of the appearance on the eighth day, a noticeable feature being, however, the prominence and large size of the eyes.

The above represents, without entering into details, the course of development up to and including the eighth day. It is evident that, although Aristotle's description, previously given, is not quite clear, he refers to the vitelline or yoke sac and the vitelline blood-vessels, and also to the allantois and the allantoic blood-vessels. Fig. 9 represents an egg with the shell carefully removed from part of one side to show the allantoic blood-vessels (in full lines,) and the vitelline blood-vessels (in broken lines), at the eighth day, which seems to correspond with the time of the latest stages in Aristotle's description, so far as it has been given above.

He next describes the appearance observable on the tenth day, and his description shows that he made a very careful examination of the egg at this period of incubation.

If the young chick be removed on the tenth day, and freed from the amnion and yolk sac, it will be seen to show an abnormally large head and large eyes, a short beak, and fairly well developed legs and wings, as shown in Fig. 10. By placing the young chick in water in a test tube and holding it towards the light, numerous feathers with their barbs and shafts can be seen by means of a lens. Aristotle says that, on the tenth day, the entire bird and its parts are distinct, its head being seen to be larger than the rest of its body, and its eyes larger than the rest of the head; if removed, he says, its eyes will be found to be black. At a later stage, he proceeds to say, the chief viscera (*i. e.*, the heart, liver, &c.) are visible, and also the gizzard and intestines, while the blood-vessels from the heart appear to extend to the yolk stalk. He also describes, in greater detail than before, the embryonic membranes, showing that he had examined the allantois, lying beneath the shell membrane, the yolk sac, and the amnion which, he says, is

about the embryo itself, and separates it from the fluid.* He seems to mean that the embryo is separated from the remains of the white of the egg by the amnion; it is not evident, from his description, that he was aware that the amnion encloses fluid which bathes the embryo.

He next passes on to about the twentieth day, when the chick, he says, chirps when the egg is disturbed. The head of the chick, he says, is over the right leg, and its wing is over the head. This is sufficiently accurate to show that he carefully examined the position of the chick about the twentieth day, for, at that time, the beak may be seen pushed under the right wing, while the right claw rests almost against the head. He also refers to the allantois, beneath the shell membrane, about the twentieth day, and again mentions the yolk sac. He compares them with the chorion, or fœtal membrane, in mammals, and states correctly that the allantois falls away, while the yolk within the yolk sac is withdrawn into the body of the chick.

Referring to the pigeon, Aristotle says that on the day before the young one is hatched, the egg is damaged or perforated,† but it is not clear whether he believed that the young one or the old ones did this. Albertus Magnus, who seems to be translating a version of the above passage, clearly states that the young pigeon breaks a piece out of the shell with its bill. His translation, given by Aldrovandi,‡ reads: "*In fissura ovi primo Columba parvula in eo existens, penetrat testam anteriore parte rostri sui, ita ut testa elevetur ad magnitudinem grani tritici, et postea dividit eam in duas partes, et exit pullus.*"

* *H. A.* vi. c. 3, ss. 3-5. † *H. A.* vi. c. 4, s. 2.
‡ *Ornithologia*, vol. ii. 1610, Frankfurt, p. 184, first column.

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CHAPTER XV.

CLASSIFICATION OF ANIMALS.

It is only by collating numerous passages scattered throughout his works that Aristotle's views on the classification of animals can be ascertained. These passages show that he attempted to make a systematic classification, but that, even for the animals known to him, it was incomplete. Apart from this incompleteness, very different views have been held respecting the value of his classification. Ray, when treating of viviparous quadrupeds, showed his appreciation of it by adopting part of Aristotle's classification,* and both Cuvier and Owen, who believed that Aristotle made a systematic classification, more or less elaborate, spoke of it in highly appreciative terms. On the other hand, Agassiz and Whewell, while fully recognizing Aristotle's attempts to deal with the differences and resemblances of various animals, held that he did not propose any regular classification.

Aristotle certainly defined a few groups of animals, particularly the *Ketode* and *Lophoura*, in such a way that groups corresponding with them are to be found in modern systems of classification, but, in most cases, what appear to be his classificatory terms are not sufficiently precise, while their use often causes the same animals to fall into more than one class, or brings into one class animals having no close natural affinities. Examples of these defects are well seen in the manner in which he deals with the dental characters of animals. Not only carnivores, for instance, but also reptiles and most fishes are included by him among his *Carcharodonta*, or animals with sharp, interlocking teeth, and the same animals, *e.g.*, horses, are included both among his *Anepallakta*, or animals with teeth having flat crowns, and among his *Amphodonta*, or animals with front teeth in both jaws.

* *Syn. Meth. Anim. Quadr. et Serp. Gen.*, 1693, pp. 56 *et seq.*

Defects of this kind are to be found in many systems of classification formed long after Aristotle's time, and it is but fair to say that, considering the early period in which he lived, he had clear conceptions of some of the chief features of difference and similarity in animals, and that he set forth these features and employed terms some of which were certainly terms of classification. Further, several of his groups were based on a consideration of essential, and not arbitrary, characters of the animals composing them, and many causes of difference were taken into account, so that Aristotle may be fairly said to have attempted to form a natural system of classification. For these achievements, and they are considerable, he is entitled to have the credit. More than this, perhaps, cannot be claimed for him, yet the nature of his zoological writings has often led to attempts to do this. For, reading them in the light of modern zoological knowledge, it is easy to interpret his statements as evidence of an elaborate scheme of classification, and, when admiration for Aristotle is excessive, as it was in Cuvier and Owen, it becomes natural to read into his words meanings which, probably, he himself never intended.

In the development of a science, a desire to classify very soon shows itself, but, as Whewell has shown, the formation of a systematic classification follows naturally only after vast numbers of observations have been carefully made and compared. Therefore, such a classification is not to be expected at a very early stage in the development of zoological knowledge, such as that in Aristotle's time. Yet he formed some general ideas of a classification based on a consideration of structure and mode of life, thus forming groups, such as his *Ketode*, *Selache*, *Malakia*, and *Entoma*, which could be more easily described in this way. In the performance of this task he made serious mistakes, but, as Whewell admits, he may justly be regarded as the great Figure in the prelude to that formation of Systems which took place in later times.

Aristotle repeatedly uses two classificatory terms, γένος (*genos*) and εἶδος (*eidos*), which are of very great importance, but, before setting out the meanings of these terms, it will be necessary to consider the meanings of the terms ὑπεροχή (*hyperoche*), ἔλλειψις (*elleipsis*), and ἀναλογία (*analogia*), which are of importance in his conceptions of γένος and εἶδος.

Aristotle says that animals, such as birds, which have

parts, feathers for instance, of the same kind, but differing in *hyperoche* or *elleipsis*, should be put in the same *genos*.* He also says that *hyperoche* and *elleipsis* may be taken to mean the greater and the less, respectively.†

Numerous passages show that the "greater" and the "less" should be interpreted in a wide sense. Differences in size and number, such as, for instance, in the lengths of birds' beaks, wings, and legs, the widths of their tongues, and the numbers of their feathers,‡ differences in hardness or softness, roughness or smoothness, of the parts of animals,§ and the presence or absence of certain parts, such as crests or spurs,‖ are given as examples of excess and deficiency, or the greater and the less.

According to Aristotle, the parts of some animals are not the same, nor do they differ merely in excess or deficiency, but in a different way according to an *analogia* or proportion. Such an *analogia* exists between hands and claws, nails and hoofs, and feathers and fish-scales, for, what a feather is in a bird, the same is a scale in a fish.¶ Further, he says that animals which have a part merely analogous to a part in certain animals should be grouped separately from these, *e.g.*, fishes should be grouped in one *genos*, and birds in another, because the scales of fishes have only an analogous resemblance to the feathers of birds.**

Numerous passages in Aristotle's works show clearly that he was constantly mindful of the idea that there exist, in some animals, component parts which may be considered to take the place of certain parts in other animals. In addition to the examples already given, a relation of this kind is said to exist between the forefeet of quadrupeds and hands,†† between the brain of a vertebrate and the "brain" of an octopus,‡‡ and between fish-bone and the cuttle-bone of *Sepia* or the pen of *Loligo*.§§ A consideration of these passages, with their contexts, justifies us in believing that Aristotle was the originator of the theory of analogies, and this is in accordance with his statement:—"By 'analogon' is meant that, while some animals have a lung, others have something in place of it, and that some animals have blood,

* *H. A.* i. c. 1, s. 2; *P. A.* i. c. 4, 644*a*.
† *H. A.* i. c. 1, s. 3.
‡ *H. A.* i. c. 1, s. 3; *P. A.* i. c. 4, 644*a*, iv. c. 12, 692*b*.
§ *H. A.* iv. c. 4, s. 6; *P. A.* i. c. 4, 644*b*.
‖ *H. A.* i. c. 1, s. 3.
¶ *Ibid.* i. c. 1, s. 4.
** *P. A.* i. c. 4, 644*a*.
†† *H. A.* ii. c. 1, s. 2.
‡‡ *P. A.* ii. c. 7, 652*b*.
§§ *Ibid.* ii. c. 8, 654a.

but others have an 'analogon,' which has the same power, or function, as blood."*

In Aristotle's idea of analogy, similarity of functions of the analogous parts is certainly included, but there is a passage, difficult to understand, which appears to introduce another factor, that of correspondence in the positions of certain parts of different animals; for, in *P. A.* iv. c. 5, 681*b*, he says that it is evident, from the position of the so-called *mytis* of a cephalopod, that this part is the *analogon* of the heart of other animals. This is proved, he adds, by the sweetness of its contained liquid, which is of the nature of blood. It is probable that the *mytis*, to which he refers, was the liver. He also says, in *H. A.* i. c. 6, s. 2, that a scute corresponds in position with a scale, and, in numerous passages, he refers to a relationship between such parts as the arms of Man, the forelegs of quadrupeds, the wings of birds, and the pectoral fins of fishes, which are now known to be homologous parts. Agassiz says:—"Though Aristotle already knew that the scales of fishes correspond to the feathers of birds, it is but recently that anatomists have discovered the close correspondence which exists between all the parts of all animals belonging to the same type, however different they may appear at first sight. Not only is the wing of the bird identical in its structure with the arm of man or the foreleg of a quadruped, but it agrees quite as closely with the fin of the whale or the pectoral fin of the fish; . . . But this correspondence is not limited to the skeleton; every other system of organs exhibits in these animals the same relations, the same identity in plan and structure, whatever be the differences in the form of the parts, in their number, and even in their functions."†

It cannot be decided to what extent, if any, Aristotle was thinking of the plan of structure of the parts, when he compared them, but it is clear that he was referring chiefly to their functions, positions, and mere external resemblances.

Two very important terms of classification, employed by Aristotle, may now be considered, *viz.*, *genos* and *eidos*. These are often translated as "genus" and "species" respectively. In many cases, *eidos* may be translated fairly well in this way, but *genos* usually signifies a class, an order, or a family.

* *P. A.* i. c. 5, 645*b*.

† *An Essay on Classification*, 1859, pp. 25, 26.

Singly or in association these terms occur in not less than three hundred passages in Aristotle's zoological works, and also in many other passages, chiefly in his *Organon*. Most of these passages merely give examples of the use of the terms, but some explain their meanings, and the following discussion is based on several of these explanatory passages.

Particular animals, or individuals, such as Socrates or Coriscos, are *essences*, or actual existences, exhibiting differences which distinguish one from another.* These *essences* have certain features in common, and a group may be formed of such *essences*. Such a group may be defined by means of the term *eidos*, provided the common features more closely indicate the nature of the *essences* included in the group, or by means of the term *genos*, if the common features indicate the nature of the *essences* less closely. Thus, the nature of Socrates or Coriscos is more closely defined by the name *Man* than by the name *animal*, which, in this case, represent *eidos* and *genos* respectively.†

Animals of which the parts, internal as well as external, are the same, belong to the same *eidos*,‡ *e.g.*, Man constitutes one *eidos*, and the horse another,§ and Aristotle also states that the parts necessary to an animal, *e.g.*, the parts for receiving and digesting food, the locomotory parts, and some of the sense organs, should be the same in animals belonging to the same *eidos*.‖ Differences in essential, and not accidental, features should alone be considered, and, among examples of accidental features or qualities, he mentions the whiteness of snow and the equivalence of the angles of a plane triangle to two right angles.¶ Evidently, although he says that the parts of animals belonging to the same *eidos* should be the same, he does not mean that these parts should be alike in all respects. He often refers, in fact, to differences in colour, shape, and relative sizes of parts, such as, for instance, the eyes, ears, and locomotory and other parts, in different individuals of the same *eidos*.

The capability of generating fertile offspring has often been considered to be important in defining a species. Aristotle also considered it to be important in connection with his views on *eidos*. He says that animals of the same

* *P. A.* i. c. 4, 644*a*; *De Long. et Brev. Vitæ*, c. 1; *Categ.* c. 3.
† *Categ.* c. 3.
‡ *H. A.* i. c. 1, s. 2.
§ *Topica*, i. c. 5, s. 2.
‖ *Politica*, iv. c. 3, ss. 9 and 10.
¶ *Topica*, iv. c. 1, ss. 1–3; *P. A.* i. c. 3, 643*a*.

eidos generate animals of the same *eidos* as themselves, and that animals not of the same *eidos*, such as the horse and the ass, generate animals of a different *eidos*.* The *Hemionoi*, or half-asses of Syria, are so called, he says, because of their likeness to the ass, although they are not of the same *eidos*, for they certainly breed among themselves.† Agassiz, referring to this passage, says:—"Aristotle already considers fecundity as a specific character.‡

On the whole, Aristotle's idea of an *eidos* was much like the modern idea of a species, but there are many passages in *H. A.* viii. and ix., which show that his *eidos* often had, in practice, very much the same meaning as the modern term *genus*.

The term *genos* is of very wide signification, and denotes a group of animals with parts of the same kind, but differing in excess and deficiency; § on the other hand, animals with parts which resemble one another only by analogy belong to different *gene*.‖

In accordance with the principles thus laid down, Aristotle forms a *genos* of *Ornithes*, and another of *Ichthyes*, both of the first magnitude, *i.e.*, containing blood; he also forms a third *genos*, the *Selache*, comprising fishes in which cartilage takes the place of bone. He found difficulties in the further application of this method, for he says that it is not easy to arrange all animals in this way, because so many of them present the same analogous structure.¶ In the more difficult cases, then, he has recourse to other means, and bases the formation of his *gene*—the *Kete* or *Ketode*, *Malakia*, *Malakostraka*, *Ostrakoderma*, and *Entoma*, and the small group of the *Lophoura*—on the existence of certain structural features.

The above are the best-defined of Aristotle's *gene*, and constitute the best proof that he attempted to form a systematic classification. He says that his *Ornithes*, *Ichthyes*, and *Ketode* are his most important classes (*gene megista*), because they include animals with blood, and that the *Malakia*, *Malakostraka*, *Ostrakoderma*, and *Entoma*, animals without blood, are important classes (*gene megala*), there being no important *gene* other than these.** In various other passages, he speaks of a *genos* of snakes, one

* *G. A.* ii. c. 8, 747*b*, and 748*a*.
† *H. A.* i. c. 6, s. 3.
‡ *Op. cit.* p. 301.
§ *H. A.* i. c. 1, s. 2; *P. A.* i. c. 4, 644*a*.
‖ *H. A.* ii. c. 1, s. 1; *P. A.* i. c. 4, 644*a*.
¶ *P. A.* i. c. 4, 644*a*.
** *H. A.* i. c. 6, s. 1.

of lizards, one of frogs, one of viviparous quadrupeds, and one of oviparous quadrupeds, but they are not described as *gene*, in the same way as, for instance, the *Ketode*. The chief reason for this appears to be that he was influenced by the popular grouping of animals, and preferred to describe separately many animals, such as, for example, monkeys, bears, and chamæleons, which the common people had not included in groups known by popular names.*

In addition to the groups referred to above as being the ones best-defined by Aristotle, there are a few others which may be included in his classification, because he describes them sufficiently clearly to enable them to be identified with orders or families of modern classifications. The groups referred to are included, therefore, in the subjoined tabular representation of Aristotle's classification. The numbers following the various groups represent approximately the numbers of different kinds of animals referred to by Aristotle :—

A. Enaima [*Vertebrata*]. (372.)
  1. Kete or Ketode [*Cetacea*]. (4.)
  2. Viviparous animals with feet [*Mammalia* other than *Cetacea*]. (62.)
    a. Non-amphodonta [*Ruminantia*].
    b. Monycha [*Solidungulata*].
      1. Lophoura [*Equidæ*].
      2. Monycha other than Lophoura [not classified].
    c. Viviparous animals with feet, other than above [not classified].
  3. Ornithes [*Aves*]. (170.)
    a. Gampsonyches [*Raptores*, chiefly].
    b. Steganopodes [*Natatores*].
    c. Peristeroeide [*Columbidæ*].
    d. Apodes [Swifts, Martins, and Swallows].
    e. Birds other than above [not classified].
  4. Oviparous quadrupeds [*Reptilia* and *Batrachia* chiefly]. (20.)
  5. Ichthyes [*Pisces*]. (116.)
    a. Selache [*Elasmobranchii* + *Lophius*].
    b. Fishes other than above [not classified].

* *H. A.* i. c. 6, s. 8, ii. c. 11, s. 1; *P. A.* i. c. 4, 644*b*.

B. Anaima [*Invertebrata*]. (120.)

1. Malakia [*Cephalopoda*]. (6.)
2. Malakostraka [*Malacostraca*]. (16.)
3. Ostrakoderma [*Mollusca* (other than *Cephalopoda*), *Echinodermata*, and *Ascidia*]. (25.)
4. Entoma [*Insecta*, *Arachnida*, and *Chilognatha*, chiefly]. (60.)
5. Spongoi [*Spongidæ*]. (4.)
6. Akalephæ [*Cœlenterata*]. (2.)
7. Anaima other than above [not classified]. (7.)

A special interest is connected with the two main divisions, *viz.*, *Enaima* and *Anaima*, in the above scheme. The distinction between them was used by many zoologists until Lamarck and Cuvier used the almost equivalent terms, *Vertebrata* and *Invertebrata*, the latter of which, like Aristotle's *Anaima*, is open to the objection that it is of a purely negative character.

CHAPTER XVI.

ARISTOTLE'S ANAIMA, OR ANIMALS WITHOUT BLOOD.

The number of *Anaima* described or mentioned by Aristotle is about one hundred and twenty, and not less than one-half of these belong to his *Entoma*. Many of his statements, mostly relating to the anatomy of the *Anaima*, have been discussed in the preceding chapters. Some of his remaining statements, chiefly about those *Anaima* which can be fairly well identified, will be discussed next.

Aristotle gives a description of three kinds of sponges, sufficient to show that they belong to the horny sponges (*Ceratosa*), including the ordinary sponges of commerce, and he also gives a description of some sponge-like form of life, called *Aplysia*, because, unlike sponges, it remained black when washed.* One kind of sponge, which he says is compact or close in texture (πυκνός) and softer than the others, may be the fine Turkey sponge (*Euspongia officinalis*, var. *mollissima*); another kind, called the sponge of Achilles, very thin, compact, and strong, and commonly laid under helmets and greaves to deaden the effects of blows, may be the lappet variety of Turkey sponge, or, possibly, the brown Turkey or Zimocha sponge (*Euspongia zimocca*); Aristotle's remaining sponge, having a larger base of attachment, and further characterized by being loose in texture (μανός) and larger than the other sponges, seems to be the common bath sponge (*Hippospongia equina*).

Aristotle says that, on the upper parts of sponges, are hemmed-in passages or ducts (*porοi*), four or five of which are conspicuous, and that some believed that the food of the sponges entered through these.†

For two thousand years after Aristotle's time, it was believed that currents of water entered the large passages of a sponge, and it was not until Dr. Grant, after very careful observations, concluded that water was drawn into the

* *H. A.* v. c. 14, ss. 2–6. † *Ibid.* v. c. 14, s. 5.

minute apertures of the sponge and ejected through the larger passages, now called *oscules*, that this error was fully corrected.*

Sea-anemones and medusæ were included by Aristotle under the name *Akalephe* or *Knide*, each meaning a nettle. He says that this group of animals is peculiar, and that some live attached to rocks, while others are free.† Speaking of the sea-anemones, he says that they have a central mouth and that they seize, as it were by a hand, small fishes that come in their way, and, probably referring more particularly to medusæ, he says that they can sting so much that the flesh is made to swell.‡

Aristotle's *Ostrakoderma*, one of his four great classes of *Anaima*, included molluscs (other than cephalopods), echinoderms, and ascidians, the last two being peculiar kinds of *Ostrakoderma*.§ The typical animals of this class were snails and oysters, having their internal parts fleshy, but their external parts hard and brittle.‖

The main characteristics of the whelk (*Buccinum*) are clearly stated by Aristotle. He calls it *Keryx*, and states that its shell is spiral and rough,¶ and that it has a powerful proboscis,** and he also notices its operculum and its egg capsules.†† He erroneously believed that the proboscis was the effective means used by the whelk in boring through shells and other hard substances, whereas it is the radula.

The most interesting gastropods described by Aristotle are his *Porphurai*, which included *Murex brandaris*, in particular, *M. trunculus*, and some species of *Purpura*. He says that the *Porphura* has a spiral shell and a powerful proboscis.‡‡ This mollusc makes, he says, the so-called honeycomb (egg capsule), which is not, however, hollowed out like a honeycomb, but composed of what may be compared to the white pods of certain plants; *Porphurai*, he adds, are not produced from the honeycomb, which is of the nature of excreta.§§ He also refers to the operculum.‖‖ As in the case of the *Keryx*, he erroneously believed that the proboscis of *Porphura* was used for boring hard substances.

It is well known that the famous Tyrian dye was prepared

* "Observations, &c., on the Sponge," *Edinburgh Philosph. Journ.*, vol. xiv. 1826, pp. 117–9.

† *H. A.* iv. c. 6, ss. 4 and 5.

‡ *Ibid.* iv. c. 6, s. 4.

§ *P. A.* iv. c. 5, 680*a*.

‖ *H. A.* iv. c. 1, s. 2.

¶ *Ibid.* iv. c. 4, ss. 1 and 3.

** *Ibid.* iv. c. 4, s. 8.

†† *Ibid.* v. c. 13, ss. 1 and 7.

‡‡ *Ibid.* iv. c. 4, ss. 1 and 8.

§§ *Ibid.* v. c. 13, s. 1.

‖‖ *Ibid.* v. c. 13, s. 7.

from species of Murex and Purpura. Aristotle gives a rather full account of the preparation of a similar dye from his *Porphurai*. The pigment, he says, appears to extend, like a duct or vessel, through a white membrane between the *mecon* (or liver) and the neck, and when this membrane is taken away and squeezed the pigment wets and stains the fingers.* The small shells, he says, are pounded up without removing the molluscs, because these are not easily removed, but the molluscs are removed from the large shells, and the pigment taken out.†

The pigment is found, very much in the way Aristotle says, near the hinder part of the neck, and lies in a duct or vein there. It is of about the consistency and colour of cream before exposure to the air, which changes it to a purple tint.

A gastropod, called by Aristotle *Nerites*, cannot be satisfactorily identified. He says that it has a smooth, large, rounded shell, similar in form to that of the whelk, that its *mecon* is red, and that some kind of crustacean sometimes lives in its shell.‡ It would seem, from *H. A.* v. c. 13, s. 8, that the *Nerites* lived attached to rocks, and, in a passage in which he incorrectly asserts that all molluscs with spiral shells have an operculum, he refers to that of *Nerites*.§

Prof. Forbes identified the *Nerites* with littoral forms of *Trochus*, found abundantly along the rocky shores of the Ægean.‖

The above are the most interesting examples of Aristotle's molluscs with coiled shells, in which, he says, the flesh-like parts can be concealed to a very large extent.¶ From a series of passages, in *H. A.* iv. c. 4, s. 2, it is sufficiently clear that he grouped molluscs which have not coiled shells (*stromboi*) into univalves (*monothura*) and bivalves (*dithura*).

Aristotle's typical example of his *monothura* is the patella or limpet, called by him *Lepas*, which, he says, has its flesh-like parts exposed,** and lives attached to rocks.††

Of Aristotle's *dithura*, his *Pinna*, *Kteis*, and *Solen* will be discussed.

* *H. A.* v. c. 13, s. 4.
† *Ibid.* v. c. 13, s. 5.
‡ *Ibid.* iv. c. 4, s. 17.
§ *P. A.* iv. c. 5, 679*b*.
‖ *Travels in Lycia, &c.*, 1847, vol. ii. p. 110.
¶ *H. A.* iv. c. 4, s. 1.
** *Ibid.* iv. c. 4, s. 2.
†† *Ibid.* iv. c. 4, s. 18.

The valves of *Pinna* are rough, according to Aristotle, but not ribbed,* and, secured by means of a byssus, they grow up erect in the sand or mud.† He also says that a small crab, the *Pinnoteres*, or *Pinnophylax* (guardian of the pinna), lives within the shell.‡ It is well known that a small crab lives in the gills and mantle of several lamellibranchs, such as, for example, *Pinna squamosa*, of the Mediterranean.

Some of Aristotle's most interesting statements about the *Kteis* (pecten), relating to its sense organs and mode of progression, have been discussed already in Chapters xii. and xiii. respectively. He says also, speaking of its valves, that they are ribbed, and that the large kinds of pecten have one valve flat.§ It is true that the common edible pecten and some others have the left valve flat or nearly so.

The solens are sufficiently clearly described by Aristotle. He says that their valves are smooth,‖ and that they live in sandy shores, remaining in one place, but not fixed in it, for they can withdraw themselves into the sand, when alarmed.¶ His suggestion that solens can see has been discussed in Chapter xii.

Most of the molluscs described by Aristotle are marine, but he also clearly refers to various snails of the genus *Helix*, which he calls by the name *Kochlias*. He says that the terrestrial *Kochliai* hybernate, and, during the period of hybernation, have an operculum.** He also says that these *Kochliai* are devoured by pigs and partridges.††

Sea-urchins and star-fishes were included by Aristotle among his *Ostrakoderma*, but were considered by him to be exceptional forms. Speaking of sea-urchins (*Echinoi*), he says that there are several kinds, one having large and edible ova, another, called *Echinometra*, which is the largest of the sea-urchins, and a third kind having large and hard spines, and living in many fathoms of water.‡‡ He also refers to two deep-sea and rare forms, *viz.*, *Spatangos* and *Bryttos*, and some white *Echinoi*, of longer form than the others, and having somewhat small and soft spines; these white *Echinoi* were found near Torona, in Macedonia.§§

It is not easy to identify the above-mentioned echino-

* *H. A.* iv. c. 4, s. 3.
† *Ibid.* v. c. 13, s. 8.
‡ *Ibid.* v. c. 13, ss. 8 and 9.
§ *Ibid.* iv. c. 4, ss. 3 and 12.
‖ *Ibid.* iv. c. 4, s. 3.
¶ *Ibid.* iv. c. 8, s. 18, v. c. 13, ss. 8 and 10.
** *Ibid.* viii. c. 16, s. 1.
†† *Ibid.* ix. c. 25, s. 3.
‡‡ *Ibid.* iv. c. 5, ss. 1 and 2.
§§ *Ibid.* iv. c. 5, ss. 2 and 3.

derms, but Prof. Forbes says that the one with large and edible ova is the purple sea-egg (*Echinus lividus*), that the *Echinometra* is probably *E. esculentus*, and that the one with hard spines is *Cidaris histrix*; he adds that *E. lividus* is the one chiefly used as food in the eastern Mediterranean.*

Star-fishes are clearly referred to by Aristotle. He says that they seize their prey and suck out their juices, and that they destroy very many oysters.† The ravages committed by star-fishes among oysters are well known.

Aristotle says that the *Aster* (star-fish) is in form like a drawing of a star, and makes the fanciful statement that it is naturally so hot that its food is at once digested.‡

The fixed ascidians seem to have been carefully examined by Aristotle. He calls them *Tethya*, and considers them to be a special kind of his *Ostrakoderma*. Their external casing, he says, is of a nature between that of skin and that of a hard shell, and can be cut like hard leather; this casing is fixed to the rocks, and in it are a water inlet and a water outlet.§ After giving this description, which is quite correct, he clearly refers to the inner muscular tunic or body-wall, enclosing the soft parts of the animal, but states incorrectly that this tunic is a sinewy (*neurode*) membrane.‖ Again, he refers to the perforated pharyngeal wall and the atrial chamber through which the water, filtered from the parts serving as food, passes to the water outlet.¶

It is evident that he placed the ascidians in a far lower position than they occupy in modern systems of classification, *viz.*, near *Amphioxus*. He was not certain that they deserved to be put even in his *Ostrakoderma*, but, concluding that they had no distinct residual matters, expressed an opinion that they were of the nature of plants.**

The most interesting part of Aristotle's work in connection with his *Entoma* relates to his selection of the animals to be included in that class. His ideas on this subject were in advance of those of many naturalists from his time till the end of the eighteenth century. His main definition is as follows:—"I call those animals *Entoma* which have incisions in their bodies, either in their ventral parts, or in these and also their dorsal parts."††

Aristotle's definition of his *Entoma* is so comprehensive

* *Travels in Lycia, &c.*, 1847, vol. ii. pp. 115–6.
† *P. A.* iv. c. 5, 681*b*.
‡ *H. A.* v. c. 13, s. 10.
§ *Ibid.* iv. c. 6, s. 1.
‖ *Ibid.* iv. c. 6, s. 2.
¶ *P. A.* iv. c. 5, 681*a*.
** *Ibid.*
†† *H. A.* i. c. 1, s. 7.

that it would include most animals of the sub-kingdoms Arthropoda, Vermes, and Echinodermata, but this definition is so qualified by other passages in his works as to show that the meaning which he gave to the term, in practice, was of very much narrower scope. His *Malakostraka*, among which he included many crustaceans, constitutes a separate *genos* or class ; * he expressly excludes from his *Entoma* animals which are not furnished with many legs, and adds that the number of legs is proportional, in some way, to the length of the body or number of its incisions, a smaller number of legs being compensated for by the presence of wings.† His *Entoma*, in fact, are chiefly butterflies and moths, beetles, bees, wasps, hornets, ants, houseflies, gadflies, gnats, dayflies, grasshoppers, locusts, spiders, scorpions, centipedes, and millipedes.

As far as he separated crustaceans from his *Entoma*, Aristotle was greatly in advance of many of the later naturalists, who classed them with their *Insecta*. Agassiz says :—"Aristotle divides this group more correctly than Linnæus, as he admits already two classes among them, the *Malacostraca* (Crustacea) and the *Entoma* (Insects)."‡ The confused classifications of the lower forms of life adopted by naturalists of the sixteenth, seventeenth, and eighteenth centuries were chiefly due to their adoption either of Aristotle's definition of his *Entoma*, without any regard for its qualifying clauses, or Pliny's definition,§ which is adapted from Aristotle's definition but includes apterous and also apodal animals which have incisions.

Aldrovandi, Swammerdam, Ray, Linnæus, and many others included, in their writings on " insects," crustaceans and some other forms of life which Aristotle's *Entoma* would not include. However, at the very beginning of the nineteenth century, Lamarck definitely separated the Crustacea and also the Arachnida from his Insecta, and, although he kept an old order, *Insecta aptera*, he deprived it of most of its former dignity by assigning to it only one genus, *viz.*, *Pulex*, Linn., with two species, of which one is *P. irritans*, or " la puce ordinaire."‖ To discuss satisfactorily the classifications of "insects" made between the time of Aristotle and that of Lamarck would be a task of

* *H. A.* i. c. 6, s. 1, iv. c. 1, s. 2; *G. A.* i. c. 14, 720*b*.
† *P. A.* iv. c. 6, 682*a* and *b*.
‡ *An Essay on Classification*, 1859, p. 305, Note.
§ *Nat. Hist.* xi. 1.
‖ *Syst. des Anim. sans Vertèbr.*, Paris, 1801, p. 314.

considerable difficulty, but it may be said that, in some essential respects, they were inferior to that indicated by Aristotle.

About sixty *Entoma* are described or mentioned by Aristotle, but only a comparatively small number of these can be satisfactorily identified. Some of these will next be considered.

He compares the hind legs of the *Akris* or locust to the two rudders used in some Greek ships, one on each side towards the stern,* and says that it produces a sound by rubbing itself with its *pedalia*, rudders or hind legs.†

He was aware that it deposits its eggs a short distance below the surface of the ground, and that its young emerge in a form very much like that of the parent, there being no distinct metamorphosis.‡ It is probable that the locust to which he refers is the migratory locust (*Pachytylus migratorius*) of south-eastern Europe.

The cicada is clearly referred to by Aristotle in many passages, although some of these passages do not correctly describe the characteristics of this insect. The cicada has a piercing and suctorial beak, by which it sucks the juices of plants. Aristotle says that the *Tettix* (*Cicada*) has a tongue-like process, by which it feeds on dew only.§ The idea that the cicada feeds on dew only is commonly found among the ancient writers.

The singing of the cicada is produced by membranes in chambers covered by scaly plates on the under side of the abdomen and just behind the thorax; the membranes are vibrated by the action of certain muscles. Aristotle says that the *Tettix* sings in consequence of the friction of the air on the membranes beneath the *hypozoma* or part close to the division between the thorax and abdomen.‖

The male cicadas sing, the females being silent; this was exceedingly well known to the Ancients, and is referred to by Aristotle.¶ He also refers to large cicadas, called *Achetai*, which sing, and small ones, called *Tettigonia*, which do not sing, or sing but little.** This passage, especially the last part of it, is difficult to understand, but it is probable, from the context in *H. A.* v. c. 24, that Aristotle intends to refer to large and small cicadas differing in species.

* *P. A.* iv. c. 6, 683*a*. † *H. A.* iv. c. 9, s. 2.
‡ *Ibid.* v. c. 17, s. 2, v. c. 23, ss. 1 and 2.
§ *Ibid.* iv. c. 7, s. 7; *P. A.* iv. c. 5, 682*a*.
‖ *H. A.* iv. c. 9, s. 2. ¶ *Ibid.* v. c. 24, s. 4. ** *Ibid.* v. c. 24, s. 1.

Cicadas have powerful ovipositors by means of which they pierce plants before depositing their eggs, and the young ones drop into the ground and go through an incomplete metamorphosis. Aristotle says that the *Tettix* deposits its eggs in certain plants and also in the ground, and he speaks of its larva and of its undergoing a kind of metamorphosis.*

The May or dayfly (*Ephemera*) seems to be described by Aristotle. He says that, about the summer solstice, casings larger than grape seeds float down the river Hypanis (the modern Bug), and, when these casings burst, an insect with four feet escapes, and lives and flies about till evening, when it dies. For this reason, he says, it is called *Ephemeron*, because it lives only about one day.† He states elsewhere that the *Ephemeron* has four legs and also four wings.‡ The Mayfly, however, has six legs, like other insects.

He uses the word *Psyche* for several kinds of Lepidoptera, but, in *H. A.* v. c. 17, s. 4, he seems to refer to a cabbage butterfly, such as *Pieris brassicæ*, for he says that the caterpillars of certain kinds of *Psyche* are produced from something smaller than millet seeds on the leaves of cabbages (*Raphanoi or Krambai*). He also refers to the loopers or *Geometridæ*, for he says that the *Penia* and *Hypera* are produced from caterpillars which form waves as they walk, the hinder parts of their bodies being bent up towards the front parts.§ The larvæ of certain kinds of *Tinea*, called by him *Setes*, are referred to in *H. A.* v. c. 26, s. 1, where he says that they are found in woollen goods and garments.

Aristotle says that his *Kouleoptera* have elytra and are without stings.‖ Several of the names used by him to denote various kinds of beetles, *e. g.*, *Kleros*, *Karabos*, and *Melolonthe*, are used to-day in a slightly modified form, but only a few of his beetles can be identified satisfactorily. His *Kantharos* is the Egyptian sacred beetle (*Scarabæus sacer*), which is found also in southern Europe. He says that it rolls up dung into balls in which its young are produced.¶ The larvæ of *Kleros*, which Aristotle says infests beehives,** are usually believed to be those of *Trichodes apiarius*, which often commit great ravages in the hives.

* *H. A.* v. c. 24, s. 3.
† *Ibid.* v. c. 17, s. 14.
‡ *Ibid.* i. c. 5, s. 7.
§ *Ibid.* v. c. 17, s. 6.
‖ *Ibid.* i. c. 5, s. 5.
¶ *Ibid.* v. c. 17, s. 10.
** *Ibid.* viii. c. 26, s. 1, ix. c. 27, s. 20.

Numerous statements about bees and wasps are made by Aristotle. Some of these have been considered in Chapter xiv., when dealing with the generation of bees. Of the rest, one is specially worthy of mention, because it is evidence of close and patient observation. He says that, during each flight, bees do not visit flowers of different kinds, but go, from violet to violet, as it were, and do not touch any other kind until they arrive at the hive.* This has long been proved to be substantially correct.

The book scorpion (*Chelifer cancroides*) is clearly referred to in *H. A.* iv. c. 7, s. 4, and v. c. 26, s. 1, where it is said to be like a scorpion, except that it has no tail, and to be of small size and found among scrolls or manuscripts.

Aristotle's *Malakostraka*, in which he includes *Karabos*, *Astakos*, *Karkinos*, *Karis*, *Krangon*, and several other crustaceans, have their external coverings soft, compared with those of his typical *Ostrakoderma*, but of a somewhat tough nature.† He sometimes calls them *Skleroderma*, or animals with harsh or hard skins.‡ Their voracity, the existence of large and also very small kinds of them, the periodic casting of their skins, their peculiar modes of progression, the carrying of their eggs beneath the abdomen of the female, and some differences between the appendages of the males and those of the females, are all mentioned by Aristotle.

He makes numerous statements about *Karabos* which show sufficiently clearly that he refers to the rock lobster (*Palinurus vulgaris*). The most important characteristics of *Karabos*, clearly given by Aristotle, are that it is elongated, and has a tail and also five swimming plates (πτερύγια) on its telson,§ that it has two large and rough horns (antennæ) in front of the eyes and two small and smooth ones (antennules) below,‖ that its eyes are large, and compared with *Astakos* (to be discussed later), its rostrum is short and cephalothorax rough,¶ and that its ova are red.**

The rock lobster, whether male or female, has chelæ on the first pair of feet, but these chelæ are not well-developed like those of the crayfish or common lobster. In different rock lobsters the extent of development of the chelæ varies, but in those I have seen the inner part of the chela was

* *H. A.* ix. c. 27, s. 7.
‡ *P. A.* ii. c. 13, 657*b*.
‖ *Ibid.* iv. c. 2, s. 5.
** *Ibid.* iv. c. 2, s. 13.
† *Ibid.* iv. c. 1, s. 2.
§ *H. A.* iv. c. 2, s. 4.
¶ *Ibid.* iv. c. 2, s. 8.

very short and bit against the proximal end of the outer part.

Aristotle's statements on this subject are inconsistent, and, in the identification of *Karabos*, it is best to follow the course adopted by Meyer,* and take the evidence furnished by Aristotle's description as a whole.

Not less than two species, *viz.*, *Homarus vulgaris*, the common lobster, and *Astacus fluviatilis*, the crayfish, are included under the name *Astakos*. Aristotle clearly gives the following characteristic features, *viz.*, chelæ large and unlike in size and form, with sharp marginal spines; four pairs of small legs, of which two pairs are chelate; antennæ much shorter and smoother than in *Karabos*; eyes smaller that those of *Karabos*; rostrum long, sharp, and rough; cephalothorax smooth and comparatively soft.† He also says that there are four antennules,‡ and was apparently unaware that there are really only two, each of which is divided. The crayfish is more particularly referred to in *H. A.* iv. c. 4, s. 19, where he says: "like the small *Astakoi*, which are found in rivers."

That Aristotle's *Karkinoi* are crabs is clear from his showing that they are decapods, rounded and not elongated, and that they are without tails, such as those of the *Karaboi* and some other crustaceans.§ He also says that the right chela is always,‖ or generally,¶ larger than the left. The right chela is larger than the left one in many crabs, but there are some in which the right and left chelæ differ but little, if any, in size, *e. g.*, specimens of *Portunus*, *Geryon*, and *Thalamita*, while there are some in which the left chela is larger than the right, *e.g.*, specimens of *Xantho*, *Ocypoda*, and *Porcellana*.

The largest crab, Aristotle says, is *Maia*, with eyes close together, and with very thin legs; this crab lives out in the sea.** It is probable that this is one of the spider crabs.

Aristotle clearly refers to some species of *Ocypoda*, or swift land crab, for he says that, on the coast of Phœnicia, there are crabs called *Hippeis*, or horsemen, because they

* *Aristoteles Thierkunde*, Berlin, 1855, pp. 240.
† *H. A.* iv. c. 2, ss. 6–9; *P. A.* iv. c. 8, 684*a*.
‡ *H. A.* iv. c. 2, s. 8.
§ *H. A.* iv. c. 2, ss. 3 and 4; *P. A.* iv. c. 8, 684*a*.
‖ *P. A.* iv. c. 8, 684*a*. ¶ *H. A.* iv. c. 3, s. 1.
** *H. A.* iv. c. 2, s. 2, iv. c. 3, s. 2; *P. A.* iv. c. 8, 684*a*.

run so fast that it is not easy to overtake them.* He also was well acquainted with more than one kind of hermit-crab, and speaks of its living in different kinds of shells.† Of the remaining crabs referred to by Aristotle there is one which can be fairly well identified. This, which he says is found in rivers,‡ seems to be *Thelphusa fluviatilis*, common in southern Europe.

There are other crustaceans which Aristotle calls *Karides*, under which he includes three kinds, *Kyphe*, *Krangon*, and a small kind of *Karis*, which never grow larger.§ The *Krangon*, which is said to have all its feet directed outwards, but its chelæ turned inwards, may be a *Squilla* or mantis shrimp.

Many of the appendages of *Squilla* are short and not seen in dorsal view; Aristotle says, apparently influenced by this, that a large part of the body of the *Krangon* is without feet.¶ The information given about the two other kinds of *Karis* is not enough to identify them, but *Kyphe* has been thought to be the common shrimp (*Crangon vulgaris*).

It is evident from Chapter xv. that Aristotle treated his *Malakia* as if they had no connection with the molluscs. He considered them to be the highest representatives of his *Anaima*, mainly because of their sexual mode of reproduction, their well-developed sense organs, and their arrangement of soft and hard parts, the former external and the latter internal, as in his *Enaima*.** He distinguishes the decapods from the octopods. He shows that the former have eight short feet, each with a double row of suckers, and also two long proboscis-like parts with suckers at their ends, a large or long body, and a hard internal support.††

Aristotle describes three decapods, *viz.*, *Sepia*, *Teuthos*, and *Teuthis*. The *Sepia*, according to him, is rather broad and has a cuttle-bone, a narrow fin extending along the whole body, and a large ink-bag situated as far as possible from the mouth.‡‡ He says that its eggs, like large, black seeds, are connected together like a bunch of fruit.§§ Both

* *H. A.* iv. c. 2, s. 2.
† *Ibid.* iv. c. 4, ss. 14–17.
‡ *Ibid.* iv. c. 2, s. 2.
§ *Ibid.* iv. c. 2, s. 1.
‖ *Ibid.* iv. c. 2, s. 4.
¶ *Ibid.*
** *Ibid.* iv. c. 1, s. 1.
†† *H. A.* iv. c. 1; *P. A.* iv. c. 9.
‡‡ *H. A.* iv. c. 1, ss. 8, 11, and 12; *P. A.* iv. c. 5, 679*a*, iv. c. 9, 685*b*.
§§ *H. A.* v. c. 16, s. 3.

Teuthos and *Teuthis* differ, he says, from *Sepia* in having a smaller ink-bag situated nearer the mouth, and a "cartilaginous" internal support, shaped like a sword.* Aristotle says that *Teuthos* differs from *Teuthis* chiefly in its much larger size (being sometimes about eight feet long), in the broader shape of its pointed end (τὸ ὀξύ), and in the arrangement of its fin, which extends along its whole body, while that of *Teuthis* is incomplete.†

Clearly Aristotle's *Sepia* is a cuttle-fish, such as *Sepia officinalis*, and *Teuthos* and *Teuthis* are large and small calamaries or squids, *Teuthos* probably being *Loligo vulgaris*. It does not seem to be possible to identify *Teuthis* satisfactorily. Frantzius believed that it was *Rossia* or *Sepiola*, each of which, it is true, has two fins quite separate and like wings on the sides of its body, but then neither of these cephalopods has its abdominal end pointed, each having it as nearly as possible hemispherical.

Aristotle describes several kinds of octopods. One of these, which he says is the largest and most common kind,‡ is *Octopus vulgaris*, and is referred to in many passages. Another kind, called *Eledone*, is stated to be the only one which has a single row of suckers on each arm.§ This kind is the modern eledone, common in the Mediterranean, but it is not possible to determine the species referred to by Aristotle. A third kind, called *Bolitaina* or *Ozolis*, is not described sufficiently to allow of its being identified.

There are two marine animals, according to Aristotle, which live in shells, one called *Nautilos* or *Nautikos*, with a shell like that of a pecten, when in its open position, and the other with a shell like that of a snail; this kind never leaves its shell, and sometimes extends its arms.‖

Aristotle's *Nautilos* was an argonaut, such as *Argonauta argo*. He gives some information about its habits, obtained probably from fishermen or sailors. He describes how it sails on the surface of the sea, with its shell upturned and propelled by winds acting on an expanded web between two of its arms, and how, when alarmed, it fills its shell with water and sinks.¶ This is a fanciful description. The shell of the female argonaut, which alone

* *H. A.* iv. c. 1, s. 12; *P. A.* iv. c. 5, 679*a*.
† *H. A.* iv. c. 1, ss. 8 and 9.
‡ *Ibid.* iv. c. 1, s. 15.
§ *Ibid.*
‖ *Ibid.* iv. c. 1, s. 16.
¶ *Ibid.* ix. c. 25, s. 12.

has a shell, has its coiled part uppermost, when the animal is at the surface, and is not caused to sink by filling with water.

It does not seem to be possible to identify Aristotle's marine animal having a shell like that of a snail. It may be a gastropod, and Prof. E. Forbes suggested *Carinaria mediterranea*,* the shell of which is, however, very small and not capable of containing the animal, when retracted. A more satisfactory identification would be furnished by gastropods of the marine genus *Atlanta*, in which the shell, although small, is capable of containing the animal, while the three lobes of the foot often project beyond the mouth of the shell. There is nothing to show, however, that Aristotle was acquainted with these gastropods. *Nautilus pompilius*, with which some have identified Aristotle's animal, is not found in the Mediterranean.

* *Travels in Lycia, &c.*, vol. ii. p. 101.

CHAPTER XVII.

ARISTOTLE'S ENAIMA, OR ANIMALS WITH BLOOD.

When expressing astonishment at the variety and extent of Aristotle's knowledge, one of the characters of Athenæus asks from what Proteus or Nereus he could have found out all that he says about fishes and other animals.* It is well known that Aristotle, living for many years close to the sea, obtained a great deal of information about fishes and other aquatic animals from fishermen, but the curiosity shown by the questioner in Athenæus is quite natural. Aristotle's knowledge of the fishes of the Mediterranean was, in fact, not only greater than that of any other ancient writer, but, if such ichthyologists as Belon, Rondelet, and Salviani are excepted, was greater than that of any other writer before the time of Risso and Cuvier. The number of kinds of fishes described or mentioned by him is not less than one hundred and ten, and about many of these he not only discusses some anatomical characteristics, but also their food, breeding habits, migrations, and modes of capture.

Most of his fishes are described separately, without any attempt being made to classify them. The cartilaginous fishes, however, are grouped together in a *genos* or class, called *Selache*, a name very familiar in various forms to modern ichthyologists.

The chief features of Aristotle's *Selache* are that they are cartilaginous,† that their gills are uncovered,‡ that they are carnivorous, live in deep waters, and throw themselves on their backs to take their prey, their mouths being placed, not directly in the front parts of their heads, but on their undersides,§ and that, excepting *Batrachos*, they are viviparous,‖

* *Deipn.* viii. c. 47.
† *H. A.* iii. c. 7, s. 6, iii. c. 8; *P. A.* ii. c. 9, 655*a*.
‡ *H. A.* ii. c. 9, s. 3; *P. A.* iv. c. 13, 696*b*.
§ *H. A.* viii. c. 4, ss. 1, 3, and 4, viii. c. 15, s. 1; *P. A.* iv. c. 13, 696*b*.
‖ *H. A.* ii. c. 9, s. 6.

or, as Aristotle explains more correctly, ovoviviparous.* He also says that they have fat livers from which oil is extracted,† and that they have no scales, but that some are rough.‡

Pliny says that Aristotle was the first to give the name *Selache* to fishes of this kind.§

Among Aristotle's *Selache* the following are included :—

Aietos	*Bous*	*Leiobatos*	*Rhinobatos*
Alopex	*Galeos*	*Narke*	*Skylion*
Batos	*Kuon*	*Pristis*	*Trygon*
Batrachos	*Lamia*	*Rhine*	*Zygaina*

The inclusion of *Batrachos*, the fishing-frog, is one of the chief defects in his work on cartilaginous fishes. Again, his assertion that all his *Selache*, except *Batrachos*, are viviparous,‖ is incorrect, for some are oviparous, *e. g.*, the true dog-fishes and rays. In other respects, however, his description of the *Selache* applies very fairly to those cartilaginous fishes with which he was acquainted.

The *Batos*, Aristotle says, is of flat form,¶ has a rough tail and body,** and buries itself in the sand, to facilitate capture of its prey.†† He also speaks of *Batis*, especially in *H. A.* vi. c. 10, s. 4, where he mentions its eggs and their hair-like filaments. These are the clearest statements made by Aristotle about *Batos* and *Batis*, which are probably the male and female respectively of the thornback skate (*Raia clavata*). The modern Greek name for a skate is Bati.

Besides describing its peculiar gill coverings, already discussed in Chapter xi., Aristotle says that the *Batrachos* has a spiny head, very rough, and many times larger than the rest of its body,‡‡ and that its tail and adjacent parts of its body are more fleshy to compensate for the small amount of flesh in the front part of its body.§§ He also describes, in unmistakable language, its lures and fishing habits.‖‖

The fishing-frog (*Lophius piscatorius*), the *Batrachos* of

* *H. A.* vi. c. 10, s. 1 ; *P. A.* iv. c. 1, 676*b* ; *G. A.* iii. c. 1, 749*a*.
† *H. A.* iii. c. 13, s. 2.
‡ *P. A.* iv. c. 13, 697*a*.
§ *Nat. Hist.* ix. 40.
‖ *H. A.* ii. c. 9, s. 6.
¶ *H. A.* v. c. 4, s. 1.
** *H. A.* vi. c. 10, s. 7 ; *P. A.* iv. c. 13, 697*a*.
†† *H. A.* ix. c. 25, s. 3.
‡‡ *G. A.* iii. c. 3, 754*a*.
§§ *P. A.* iv. c. 13, 695*b*.
‖‖ *H. A.* ix. c. 25, s. 1.

the Greeks and *Rana piscatrix* of the Romans, is described by many other ancient writers, especially Oppian of Cilicia, Pliny, and Cicero. Aristotle seems to have included it among his *Selache* partly on account of its sharp and rather large teeth, and its tuberculated skin, free from scales, and partly because he considered it to be cartilaginous. However, he admits that it is an exceptional member of his *Selache*, for he says that it has covered gills and that it is not ovoviviparous. It may be mentioned that, with respect to the nature of its skeleton, the fishing-frog occupies a position intermediate between the typical bony fishes and the cartilaginous fishes.

The term *Galeos* is of wide meaning, and includes many long, cartilaginous fishes, in contradistinction to the flat ones. Aristotle mentions several kinds of *Galeos*, and distinguishes them by names such as *asterias*, *akanthias*, and *leios*, having an analogy to the specific names used by modern zoologists.

The smooth dogfish is still called *Galeos* by modern Greeks. Aristotle says, in one passage, that *Galeos* has many pyloric cæca ;* he can scarcely be referring to the dogfish here. The name was used, in fact, for more than one kind of fish, in several ancient authors, *e.g.*, Archestratus speaks of a *Galeos* caught off Rhodes and sold for not less than a thousand Attic drachmæ.† This could scarcely be a dogfish. Aristotle also uses a group-name, *Galeoeides*, to denote several fishes having affinities with *Galeos*. In this group he included *Alopex*, *Kuon*, and *Skylion*.‡

In *H. A.* vi. c. 10, s. 5, Aristotle shows that he knew of the existence of placental fishes, for he says that the *Galeoi* (dogfishes) which are called *leioi* (smooth) have their young attached by an umbilical cord to a kind of placenta, and that, when taken away, they appear like the embryos in quadrupeds (mammals). It is well known that most of the species of *Mustelus*, and some other cartilaginous fishes, are placental; Aristotle anticipated this modern discovery.

Aristotle asserts that *Narke* lies concealed in sand or mud, and numbs any fish which comes near it, by some means within its body.§

This sufficiently clearly shows that *Narke* is the torpedo. Theophrastus, Ælian, and Oppian of Cilicia refer to this fish, but exaggerate its powers; the most interesting

* *H. A.* ii. c. 12, s. 13.
† *Deipn.* vii. 44.
‡ *H. A.* vi. c. 10, ss. 4 and 10.
§ *Ibid.* ix. c. 25, s. 2.

account of *Narke* is given, however, in Athenæus, because it shows that the fish had been subjected to experimental tests. Athenæus says that, according to Diphilus of Laodicea, the shock was not produced by all parts of the fish's body, but by certain parts only, and that Diphilus proved this by a long series of experiments.*

The torpedo was one of the food fishes of the Ancients, and is represented, with bass and red mullet, on several of the Campanian-ware fish plates to be seen at the British Museum.

The *Rhine*, according to Aristotle, produces seven or eight young at a time,† its skin is rough,‡ and tail large,§ it catches fish by lying in wait in the sand and attracting them by means of lures on its mouth,‖ and it can change its colour to match that of the place where it lives.¶

Except that it usually brings forth many more than seven or eight young ones at a time, the angel fish (*Rhina squatina*), which is still called *Rhina* in some parts of Greece, seems to be Aristotle's *Rhine*.

This name, which means a rasp or file, applies well to the angel fish, which has a skin quite rough from the presence of a vast number of tubercles. Its tail is comparatively large, it lies in wait for its prey in the manner stated by Aristotle, and it has processes or lures on or near the upper edge of its mouth. Again, according to Yarrell, it seems to show variations of colour corresponding with the nature of the ground where it is found.**

The most important statements made by Aristotle about the *Trygon* are that it is a flat fish and that its tail is long and spiny.†† These and the few other statements made by him are not sufficiently precise for the purpose of identification, but it is almost certain that his *Trygon* is the sting-ray (*Trygon pastinaca*). Other ancient writers, especially Ælian, Oppian of Cilicia, and Pliny, describe one of the most remarkable features of the *Trygon*, its caudal spine, by means of which it lacerates the flesh of its victim. Pliny says that nothing is so execrable as the *radius*, five inches long, projecting from the tail of the *Trygon* or *Pastinaca*.‡‡

It is said that the sting-ray is still called *Trygon* at

* *Deipn.* vii. 95.
† *H. A.* v. c. 9, s. 3.
‡ *P. A.* iv. c. 13, 697*a*.
§ *H. A.* v. c. 4, s. 1.
‖ *Ibid.* ix. c. 25, s. 3.
¶ *Ibid.* ix. c. 25, s. 10.
** *British Fishes*, 1859, vol. ii. p. 538.
†† *P. A.* iv. c. 13, 695*b*.
‡‡ *Nat. Hist.* ix. 72.

Paros.* This is a good instance of the apparent persistence of popular names.

The information given by Aristotle about the rest of his *Selache* is but slight, but his *Lamia* was probably a large species of shark, and his *Zygaina* was almost certainly the hammer-headed shark.

In the following table are given many of the remaining fishes mentioned by Aristotle which can be fairly well identified. The name of each fish is followed by the name of the species or genus which seems to be particularly meant, for it should be remembered that some of the names used by Aristotle denoted more than one species, or, in some cases, more than one genus.

Amia (*Pelamys sarda*)	Kyprinos (*Cyprinus*)
Atherine (*Atherina*)	Labrax (*Morone labrax*)
Belone (*Syngnathus acus*)	Muraina (*Murœna helena*)
Chelidon (*Exocœtus*)	Phagros (*Pagrus vulgaris*)
Chrysophrys (*Pagrus auratus*)	Perke (*Perca fluviatilis*)
Enchelus (*Anguilla vulgaris*)	Skaros (*Scarus Cretensis*)
Glanis (*Parasilurus aristotelis*)	Thynnos (*Thynnus*)
Gongros (*Conger vulgaris*)	Triglo (*Mullus barbatus*)
Kallionymos (*Uranoscopus scaber*)	Xiphias (*Xiphias gladius*)
Kestreus (*Mugil capito*)	

Eleven fishes, some of which are mentioned above, are of more than ordinary interest in connection with Aristotle's researches on fishes. The eleven fishes referred to are *Amia*, *Belone*, *Channe*, *Erythrinos*, *Glanis*, *Kallionymos*, *Kyprinos*, *Perke*, *Phykis*, *Psetta*, and *Skaros*.

According to Aristotle, *Amia* has strong teeth,† and a long gall-bladder extending in a zigzag course along the whole of its intestine.‡ These statements are sufficient to identify *Amia* with one of the bonitos, especially the pelamid, *Pelamys sarda*, Cuv. & Val. Rondelet was the first to identify *Amia* satisfactorily. His drawing represents it as a scombroid with numerous sharp teeth and nine pairs of bands running obliquely forwards and downwards on the sides of its body.§ Compared with the specimens in spirits to be seen at the Natural History Museum, South Kensington, or with the excellent coloured drawing of *P. sarda*, opposite p. 162 of vol. viii. of Cuvier and Valenciennes' *Hist. Nat. des Poiss.*, Rondelet's drawing,

* *Proc. Acad. Nat. Sci. of Philadelphia*, 1892, p. 240.
† *H. A.* ix. c. 25, s. 5. ‡ *H. A.* ii. c. 11, s. 7; *P. A.* iv. c. 2, 676*b*.
§ *De Pisc. Marin.* 1554, p. 238.

evidently intended to be *P. sarda*, is not good, for the snout is too blunt and the bands too highly inclined. The bands of *P. sarda* are, however, subject to variation, and it is most probable that Rondelet's *Amia* was this fish.

Aristotle says that *Belone* is a long fish,* and that it splits open to allow its comparatively few but large eggs to escape, for a slit is formed under its abdomen, and yet the splitting does not kill the fish, for the wound heals again.† Although these statements do not correctly describe what takes place, it is evident that *Belone* is one of the pipe fishes, such as *Syngnathus acus*, the eggs of which pass into the sub-caudal pouch of the male, and remain there during the process of incubation.

The three fishes *Channe*, *Erythrinos*, and *Psetta* are remarkable because Aristotle seems to have believed that they were hermaphrodite. His statements on this subject have been discussed in Chapter xiv.

Aristotle's *Glanis* has been discussed by many naturalists, but it is only comparatively recently that it has been satisfactorily identified. In addition to other information about this fish, Aristotle says that its tail is like that of a water-newt,‡ that its gall-bladder is close to its liver,§ that it is a freshwater fish depositing large ova, which are connected together like those of a frog, that the ova develop very slowly and are guarded by the male fish, which sometimes spoils the fishing-hooks with its hard teeth, and that the large *Glanides* spawn in deep water, but the smaller ones in shallow water, near the roots of a willow, or among reeds and mosses.‖

Clearly, Aristotle's *Glanis* is a siluroid fish. Pliny, Artedi, Bloch, and Cuvier identified it with the well-known *Silurus glanis*. Cuvier entertained no doubt about the correctness of this identification and pointed out that, at Constantinople, *S. glanis* was called Glanos or Glano.¶ On the other hand, Gesner was of opinion that the wels (*S. glanis*) was unknown to Aristotle, and he identified *Glanis* with a smaller species of *Silurus*.** Several centuries after Gesner's time, Agassiz, who had considerable experience of

* *H. A.* ii. c. 11, s. 7.
† *H. A.* vi. c. 12, s. 4, vi. c. 16, s. 4; *G. A.* iii. c. 4, 755*a*.
‡ *H. A.* i. c. 5, s. 3. § *Ibid.* ii. c. 11, s. 7.
‖ *H. A.* vi. c. 13, ss. 2, 4, and 5, ix. c. 25, s. 6.
¶ *Hist. Nat. des Poiss.* xiv. p. 344.
** *Nomencl. Aquat. Anim.* 1560, p. 319.

Silurus glanis of Central Europe, and was not disposed to accept Cuvier's identification, obtained six specimens of a siluroid, new to ichthyologists, from the Achelous, in western Greece.

These fishes were labelled with the local name for them, *Glanidia* (plural of *Glanidi*), and, after a careful examination, Agassiz concluded that they were the same as Aristotle's *Glanis*, agreeing with this in the form of the anal fin, the nature of the gills, the position of the gall-bladder, the connected spawn, and other characters.*

Agassiz gave the name *Glanis aristotelis* to this siluroid, but it is more usually called *Parasilurus aristotelis*. I have not been able to see a specimen of this fish, but a good description, with drawings, is given by T. Gill, who states that it watches over its eggs, which *Silurus glanis* does not, that it has four barbels, whereas *S. glanis* has six, and that it has fewer rays in its anal fin.†

The *Kallionymos*, which lives near the shore,‡ and has a gall-bladder relatively larger than that of any other fish,§ is clearly the star-gazer (*Uranoscopus scaber*). Pliny says that the *Callionymus*, which has more gall than any other fish, is also called *Uranoscopos*, from the position of its eyes.‖ The presence of a very large gall-bladder in *Kallionymos* was so well known that this fish was commonly referred to in passages descriptive of excessive anger.¶ The gall-bladder of the star-gazer is very large, and, according to Cuvier and Valenciennes,** shaped like a long-necked phial, with a duct as large as the fish's duodenum.

Aristotle's statements about the fleshy palate of *Kyprinos*,†† about its being a river fish,‡‡ and about its great fecundity,§§ clearly show that he is referring to the carp. His statements about this fish are, in fact, far more valuable than those made by other ancient authors.

Under the name *Perke*, Aristotle included both freshwater and sea perches, and it is only in a few passages that it is clear to which he refers. The freshwater perch is clearly referred to in *H. A.* vi. c. 13, s. 2, where he says

* *Proc. Amer. Acad. of Arts and Sci.*, vol. iii. 1857, pp. 325–34.

† *Annual Report of the Smithsonian Institution*, Washington, 1906, pp. 436–9.

‡ *H. A.* viii. c. 15, s. 1.

§ *Ibid.* ii. c. 11, s. 7.

‖ *Nat. Hist.* xxxii. 24.

¶ Ælian, *De Nat. Anim.* xiii 4.

** *Hist. Nat. des Poiss.* iii. p. 297.

†† *H. A.* iv. c. 8, s. 4; *P. A.* ii. c. 17, 660*b*.

‡‡ *Ibid.*

§§ *H. A.* vi. c. 13, ss. 1 and 6.

that its ova, connected together like those of frogs, are deposited among reeds in rivers and ponds.

Nest-making fishes are well known. The first record of fishes of this kind was made by Aristotle. In *H. A.* viii. c. 29, s. 3, he says that *Phykis* is the only sea-fish, "so they say," which makes nests and rears its young in them. The word used by him for "nest" is στιβάς, which means a bed of leaves or reeds. The fish referred to appears to be one of the gobies, the males of which guard the eggs, previously deposited by the females, beneath stones or aquatic plants or the concave parts of cockle or other shells.

According to Aristotle, *Skaros* was the only fish which seemed to ruminate,* its food was seaweed,† and its teeth were not sharp and interlocking like those of other fishes.‡ From Athenæus, *Deipn.* vii. 113, it seems that *Skaros* was not easily caught. Oppian of Cilicia applies to it the epithets *stiktos* (variegated), *balios* (dappled), and *glagoeis* (milky).§ Marcellus of Sida calls it *anthemoeis* (flowery).‖ Martial says in effect that the viscera of *Scarus* were of better flavour than the rest of this fish,¶ and that it was caught by means of a hook baited with a fly.** Other ancient writers, Ælian, Ovid, Horace, and Pliny, refer to *Skaros* or *Scarus*, but the passages cited above are those of most interest.

Many naturalists have tried to identify Aristotle's fish. Rondelet says that it is like a sargo in shape, fins, and spines, and that it used to be sold by some fishermen for *Sargo*.†† Belon says that it is very common off the Cretan coasts.‡‡ Under the name *Scarus Cretensis*, Aldrovandi gives a drawing of a fish with a long dorsal fin, large scales, and deep saw-edged jaws.§§ His fish is evidently a parrot-wrasse, but his description is of little value. Availing himself of the fact that *Skaros* is the modern Greek name for a fish which is very common off the Cretan coasts, Cuvier obtained, with the assistance of Count de Chabrol, French Minister of Marine, in 1827, three of these fishes. In Cuvier and Valenciennes' great work, which was continued by Valenciennes after Cuvier's death, a belief is

* *H. A.* ii. c. 12, s. 13, viii. c. 4, s. 4; *P. A.* iii. c. 14, 675*a*.
† *H. A.* viii. c. 4, s. 1.
‡ *Ibid.* ii. c. 9, s. 5.
§ *Halieut.* iv. 41, 88 and 113.
‖ *De Medic. e Pisc.* line 19.
¶ *Epigr.* xiii. 84.
** *Ibid.* v. 18.
†† *De Pisc. Marin.* 1554, p. 164.
‡‡ *Les Observ. &c., en Grèce, Asie, &c.*, 1553, i. c. 8.
§§ *De Pisc.* 1613, p. 8.

expressed that these fishes were the same as Aristotle's *Skaros* and nearly the same as Aldrovandi's *Scarus Cretensis*.* This belief was strengthened by a description of the *Skaros* of Crete, given by M. Le Mesle, in command of the 'Cuirassier,' on which the fishes examined by Cuvier were taken to Toulon. The value of this description is greater, because it was made without regard for what the Ancients said of their *Skaros*. According to M. Le Mesle, it is called *Skaro* from its leaping mode of progression, it plays about among rocks in the midst of seaweeds and other plants on which it feeds, it can be caught only after some experience, being very difficult to take with the line, its flavour is excellent, and the Turks call it "red fish" or "blue fish," according to its play of colours.† Cuvier was also informed by M. Pouqueville that the Greeks made a sauce from the liver and intestines of the Skaro,‡ a statement which explains to some extent the passage already given from Martial.

With respect to the so-called ruminating habits of *Skaros*, there seems to be a misunderstanding. Aristotle says that it appears to ruminate, and it is only some later writers, like Oppian and Pliny, who assert that it ruminates. The idea of rumination by the parrot-wrasse (*Scarus Cretensis*), which is clearly the *Skaros* of the Ancients, probably arose from its grazing or cropping off marine plants and grinding them down by a process lasting some time. It may be mentioned that Darwin, Wallace, and others who describe the feeding habits of various species of *Scarus*, many of which feed on corals, employ the words "browsing" and "grazing."

A large number of species of reptiles and amphibians exists in Greece. Thirty-one species were recorded in 1832 by the members of the French Scientific Expedition to the Morea. Aristotle describes or mentions not less than fifteen; he also describes a few not found in Greece.

His *Chelone* included *Testudo græca* and *T. marginata*, two common land-tortoises of Greece, and also *Thalassochelys caretta*, the loggerhead of the Mediterranean; this he calls *Chelone thalattia*. His description of the habits of this turtle is not quite accurate, but he knew that it leaves the water to deposit its eggs, burying them in the earth,§ and that it has powerful jaws enabling it to crunch the shells of molluscs.‖

* *Hist. Nat. des Poiss.* xiv. pp. 148–9.
† *Op. cit.* pp. 149–150.
‡ *Op. cit.* p. 151.
§ *H. A.* v. c. 27, s. 1.
‖ *Ibid.* viii. c. 3, s. 4.

Aristotle's *Emys* seems to be the European pond-tortoise (*Emys orbicularis*). According to him, it is a small water-tortoise,* but no passage in his works seems to state that it is a freshwater animal. That it is so may be inferred from *H. A.* v. c. 27, s. 1, for, after describing how *Emys* deposits its eggs in a hole in dry ground, Aristotle follows with a short but separate description of marine tortoises. Pliny clearly states that freshwater tortoises were called *Emydes* by some Greek authors.†

The Nile crocodile is mentioned by Aristotle in several passages, but he gives nothing of importance beyond the information given by Herodotus.

The gecko, probably *Hemidactylus turcicus*, and other species, is clearly indicated by Aristotle, who calls it *Askalabotes*. He says that it can walk on trees in any position, even below the branches,‡ and that it eats spiders.§ Just as, at the present day, the bite of the gecko in some parts of southern Europe is considered to be poisonous, or even fatal, Aristotle says that in some parts of Italy the bite of the *Askalabotes* is fatal.‖ Geckos are quite harmless, although their appearance is not inviting, and their food chiefly consists of spiders, flies, and moths.

Perhaps no reptiles were better known by Aristotle than the chamæleons. He probably saw many of them in western Asia, and it is evident that he dissected them. Some interesting statements relating to the anatomy of the chamæleon have been discussed in Chapters x.–xii. The rest of the statements made by Aristotle, in *H. A.* ii. c. 7, and *P. A.* iv. c. 11, are too numerous to be cited at length, and a selection only will be given. He says that it has a very long tail tapering to a point and much twisted, like a thong.¶ The outer part of each of its front feet, he says, is divided into two toes, and the inner part into three; the inner part of each hind foot is divided into two toes, and the outer part into three.** This description agrees with the peculiar arrangements of the toes of a chamæleon, but an error seems to occur, ἐντὸς for ἐκτὸς, in Schneider's Greek text.

Aristotle gives a good description of the eyes of a chamæleon and a short account of their movements,†† but, strangely enough, does not point out that each eye can

* *H. A.* viii. c. 2, s. 2.
‡ *H. A.* ix. c. 10, s. 2.
‖ *Ibid.* viii. c. 28, s. 2.
** *Ibid.* ii. c. 7, s. 2.
† *Nat. Hist.* xxxii. 14.
§ *Ibid.* ix. c. 2, s. 5.
¶ *Ibid.* ii. c. 7, s. 1.
†† *Ibid.* ii. c. 7, s. 3.

move independently of the other. When the outer skin of the eye of a chamæleon is removed, he says, a shining body, like a small bronze ring, is exposed.* This refers to the iris, which is seen, after removal of the skin, as a bronze-like ring surrounded by a series of radial bands with black pigment about their outer ends.

The change of colour of a chamæleon, Aristotle says, takes place when it is puffied out, and it exhibits a dark colour, not very different from that of a crocodile, and a pale colour, not unlike that of some lizards, variegated with dark parts, like that of a leopard. This change takes place, he adds, over the whole of its body, for its eyes and tail change like the rest of its body, but, when dying, it becomes of a pale colour, and so it remains after death.†

It is true that a marked puffing-out is noticeable when a chamæleon changes colour, during a state of agitation. The changes of colour are due, however, to the shifting of pigment granules towards or away from the epidermal layer, in branches of chromatophores beneath the skin. These changes of colour, as Prof. Poulton of Oxford suggested to me, might be compared with blushing. Aristotle's description of the various changes of colour is not clear. They depend to a large extent on the state of a chamæleon as regards fear or anger, sleeping and waking, the colours of surrounding objects, the brightness of the light, and the temperature. One which I had some time ago was nearly white, when terrified, except for some brownish spots, and, when asleep, its colour was much the same, but greyish instead of nearly white. When among trees and bushes it gradually assumed a greenish colour, with brown spots, but, when angry, it drew in large quantities of air, blowing itself out, hissing, and becoming nearly black. The changes of colour occurred over all parts of the body, except that the under parts, and especially the parts between the legs, were not nearly so sensitive as the upper parts.

The colour of the common chamæleon, after death, is usually yellowish-white, but one chamæleon, after death by chloroform, was black, except on the under parts between the legs. Prof. Poulton says that one chamæleon, which died a natural death, was of the usual light colour after death, but dark before it died.

Aristotle says that the viper, which he sometimes denotes

* *H. A.* ii. c. 7, s. 5. † *Ibid.* ii. c. 7, ss. 3 and 4.

by the masculine form *Echis*, sometimes by the feminine form *Echidna*, is the only snake which is ovoviviparous.* Vipers bring forth their young alive, and under the name *Echis* or *Echidna* may be included the common viper (*Vipera berus*), the southern viper (*V. aspis*), and the sand viper (*V. ammodytes*), which is said to be in the East what the common viper is in the West.†

Aristotle records the popular belief that the *Salamandra*, probably the common spotted Salamander (*Salamandra maculosa*) of southern Europe, puts out a fire if it walks over it.‡

One amphibian, the *Kordylos*, mentioned by Aristotle, is difficult to identify. He says that it is an amphibious quadruped having gills but no lungs, and obtaining its food on dry land,§ that it lives in marshes,‖ and that it has a thin, flat tail,¶ which is like that of *Glanis* (*Parasilurus aristotelis*), to compare a small thing with a large one.**

Gesner and Belon seem to have believed that *Kordylos* was a water newt. Cuvier says:—"It is clear that these characters," referring to those of *Kordylos*, "can belong only to the larva of the water newt, as M. Schneider has very well seen." †† Sundevall considers that Aristotle's animal is one of the water newts, and says that on each side of the back part of the head of *Triton palustris* there is an indication of the former existence of the gill slit in the presence of a fold of rather tender skin, and that an appearance such as this may have deceived Aristotle.‡‡

No animal with which Aristotle can reasonably be supposed to have been acquainted serves as a good identification of his *Kordylos*. The tadpoles of water newts, although they have during certain stages of their development external gills and four legs, do not go on dry land to obtain food, and the tadpoles of frogs have no branchial apertures when their front legs project beneath the skin. Aristotle seems to have misunderstood the nature of the respiratory organs of water newts, and his *Kordylos* is probably one of these.

Among the other reptiles and amphibians described or mentioned by Aristotle are *Batrachos* (the frog), *Phryne* (the

* *H. A.* i. c. 6, s. 2, iii. c. 1, s. 14, v. c. 28; *G. A.* i. c. 10.
† *Expéd. Sci. de Morée*, 1836, vol. iii. part 1, p. 74.
‡ *H. A.* v. c. 17, s. 13. § *H. A.* viii. c. 2, s. 5; *De Respir.* c. 10, 476*a*.
‖ *H. A.* i. c. 1, s. 7. ¶ *P. A.* iv. c. 13, 695*b*. ** *H. A.* i. c. 5, s. 3.
†† *Le Règn. Anim.* Paris, 836–7, Note on p. 47 of vol. on "Reptiles."
‡‡ *Die Thierarten des Aristoteles*, 1863, p. 187.

toad), *Typhlines* (the blind-worm), *Hydros* (the grass-snake), and *Saura*, which included the wall and other lizards. In *H. A.* i. c. 5, s. 4, he says that some say that there are winged snakes in Æthiopia. This report probably originated from the ancient representations of winged snakes, such as, for instance, those on certain Egyptian mummy cases, some of which, from Edfu, Thebes, and other places, may be seen in the Egyptian Rooms of the British Museum. Herodotus also refers to the reported existence of snakes, with wings like those of a bat, in Arabia.* All the representations referred to above, in the Egyptian Rooms, show snakes with feathered wings; there does not seem to be one with wings like those of a bat.

About one hundred and seventy birds are described or mentioned by Aristotle. Only a comparatively small number of these can be identified satisfactorily.

His *Gampsonyches* included eagles, hawks, kites, ospreys, owls, and vultures. He refers to them in many passages, and says that they are carnivorous birds with hooked beaks and claws, keen-sighted eyes, and well-developed breasts and wings.

Owls were so well known at Athens that to take one there was a useless act,† something like carrying coals to Newcastle. It is not surprising that Aristotle often refers to them. He uses not less than seven names denoting at least seven different kinds of owls. One of these names, *Glaux*, is sometimes used to denote owls in general, but the kind to which it seems specially to refer is the little owl (*Strix noctua*), sacred to Athene. The *Skops* which, Aristotle says, is smaller than the *Glaux*,‡ is probably the common scops owl. He clearly refers to the eared owls, for he says that *Otos*, which some call *Nyktikorax*, is like *Glaux*, but has feathers near its ears.§

Among diurnal birds of prey may be specially mentioned Aristotle's *Kenchris*, *Haliaietos*, and *Iktinos*. The kestrel seems to be referred to in his statements that *Kenchris* lays four or more eggs, which is more than those of other birds of its kind, and that the eggs are ochre-coloured or reddish-brown.‖ The statement about the number of eggs is substantially true of the hawks and other diurnal birds of prey, most of which lay two, three, or four eggs.

* ii. 75, 76, iii. 109.
† Aristoph. *The Birds*, 301.
‡ *H. A.* viii. c. 5, s. 2.
§ *Ibid.* viii. c. 14, s. 6.
‖ *Ibid.* vi. c. 1, s. 2, vi. c. 2, s. 2.

The kestrel lays four, five, or sometimes six eggs, usually mottled or blotched with reddish-brown.

The *Haliaietos* or sea eagle, according to Aristotle, has a large, thick neck, curved wings, and broad tail,* and it lives near the coast and strikes down water birds.† He relates a popular belief that the old birds kill any of their young ones which are unable to gaze on the sun before they are fledged.‡

Aristotle gives very little information about the kite, which he calls *Iktinos*. He says that its young ones are usually two, sometimes three, or, in the Ætolian kites, four in number, and that the period of incubation is twenty days.§ His estimate of the number of young ones is rather too low, for the kite usually has three or four. The period of incubation of the kite I do not know.

The *Steganopodes*, or web-footed birds, which can be identified, are *Kyknos* (the swan), *Chen* (the goose), *Netta* (the wild duck), and *Laros*, which includes sea-gulls and terns, while those which cannot be so well identified comprise *Kolymbis*, *Boskas*, and *Aithyia*.‖

The *Kolymbis* is of special interest in connection with Aristotle's views on the structure of the feet of his *Steganopodes*. He includes *Kolymbis* among the heavier birds, living in the vicinity of rivers and lakes,¶ and he probably had it in mind in *P. A.* iv. c. 12, 693*a* and 694*b*, where he says that birds which have their toes separated, but flattened, belong to the same group as web-footed birds, and that some swimming birds are fully web-footed, while others have their toes separated from one another, but there is an expansion along the whole length of each toe, something like an oar-blade.

Aristotle's *Kolymbis* seems to be a grebe, *viz.*, the great crested grebe (*Podicipes cristatus*), which frequents the fresh waters of Greece, Turkey, and Asia Minor, is one of the web-footed birds, according to Aristotle's definition, and may be included among the heavier water birds, for its total length is nearly two feet, although its body is not larger than that of a wild duck of moderate size. Dionysius makes statements about *Kolymbos* (probably another name for *Kolymbis*), which are quite consistent with the aquatic habits

* *H. A.* ix. c. 22, s. 3.
† *Ibid.* ix. c. 23, s. 3.
‡ *Ibid.*
§ *Ibid.* vi. c. 6, s. 2.
‖ See also an article by me entitled "On the Identification of some of the Birds mentioned by Aristotle," in *The Zoologist*, 1903, pp. 241–53.
¶ *H. A.* viii. c. 5, s. 8.

of the great crested grebe. He says that it is almost always afloat, and that it swims against the winds so that it may not be driven unwillingly to land.*

The great crested grebe is emphatically in its element on the water, and, during windy weather, I have seen this bird, on the Tring reservoirs, swimming out against wind and waves with evident enjoyment, while coots and other birds were in smoother water. The little grebe or dabchick is clearly described in Athenæus,† as the little *Kolymbis*.

All that Aristotle says about *Boskas* is that it is one of the heavier web-footed birds living in the vicinity of rivers and lakes, and that it is like a duck, but smaller.‡ This is not sufficient to identify it, but, making use of the characters, given in Athenæus to the male *Boskas*, *viz.*, short beak and pencilled plumage,§ the *Boskas* has been supposed to be the wigeon or the common teal.

From the scanty information given by Aristotle about *Aithyia*, it seems that it is a sea-bird which hatches out two or three young ones, among the rocks, in early spring, that it does not migrate, and that it feeds on animals washed ashore.‖ A bird, called *Aithyia*, is described by Dionysius,¶ and referred to by Homer, Arrian, Æsop, Theophrastus, Ælian, Athenæus, and Hesychius, and what appears to be the same bird is described by Horace, Virgil, and Pliny under the name *Mergus*. These descriptions and references are consistent with its being a voracious sea-bird, more especially a gull. Many attempts have been made to identify *Aithyia*. William Turner, Dean of Wells, identifies it with a cormorant.** Gesner seems to consider it to be a goosander, or a gull.†† Belon identifies *Aithyia* with a bird to which he assigns many features, some of which are to be found in the razor-bill, and his drawing of *Aithyia* represents a web-footed bird, without the first toe, and with a well-developed beak.‡‡ Sundevall argues that *Aithyia* is a gull,§§ and D'Arcy W. Thompson says it is probably a large gull, *e.g.*, *L. marinus* or *L. argentatus* (the herring gull).‖‖

Excepting the herring-gulls, the birds mentioned above

* *Ixeutica*, ii. 12.
† *Deipn.* ix. 52.
‡ *H. A.* viii. c. 5, s. 8.
§ *Deipn.* ix. 52.
‖ *H. A.* v. c. 8, s. 4, viii. c. 5, s. 7.
¶ *Ixeutica*, ii. 5.
** *Avium . . . apud Plin. et Aristot. . . . Historia*, 1544, not paged.
†† *Hist. Anim.* iii. 1555, p. 119.
‡‡ *L'Hist. de la Natur. des Oyseaux*, 1555, pp. 179–80.
§§ *Die Thierarten des Aristoteles*, 1863, p. 158.
‖‖ *Glossary of Greek Birds*, 1895, p. 17.

do not furnish an identification at all satisfactory, for they are either very rare in Grecian waters, or they differ from *Aithyia* in breeding habits, or in the nature of their food, and, among the herring-gulls, that which furnishes the best identification is the one considered by some to be a distinct species, *viz.*, *L. leucophæus* (the yellow-legged herring gull). This bird is very common in Greece, and nests among the rocks rather early in spring. It is described in Sharpe and Dresser's *Birds of Europe*, 1871–81, vol. 8, where it is stated (Seebohm's notes being quoted) that this is almost the only kind of gull met with in the Mediterranean, both in spring and summer, and that Seebohm visited some breeding places of this bird in the Isle of Makree, and, from what he saw, concluded that it must have had eggs about the middle of April.

The *Peristeroeide* of Aristotle include *Peristera* (the domestic pigeon), *Phatta* (the wood pigeon, still called *Phassa* or *Phatta* in modern Greece), *Oinas* (the rock pigeon), and *Trygon* (the turtle dove, still called *Trygon* in modern Greece). His statements about these birds are numerous, and some only, relating to *Phatta* and *Trygon*, will be considered.

Aristotle says that *Phatta* is the largest and *Trygon* the smallest of his *Peristeroeide*.* According to him, the *Trygon* is never seen in Greece during the winter, but only in summer, and this he explains by its migrating to and from Greece and also by its hiding itself.† The turtle dove is a particularly good example of a summer migrant. It arrives in Greece in April, and leaves in August.‡ His statements about *Phatta* are inconsistent, for he says that it is always seen in Greece,§ and that it does not winter there.‖

Referring to the autumnal disappearance of birds generally, Aristotle says that they do not all migrate to warm regions, as some say, but those which are near the regions where birds of their own kind are always found, migrate thither, while some which are far away from the regions where birds of their own kind are always found, do not migrate, but hide themselves.¶ This erroneous view about migrations was held for many centuries after Aristotle's time, and is still to be found as a popular belief.

* *H. A.* v. c. 11, s. 2. † *Ibid.* viii. c. 5, s. 5, viii. c. 14, s. 5, viii. c. 18.
‡ Sharpe and Dresser's *Birds of Europe*, 1871–81, vol. 7. Section on *Turtur vulgaris*.
§ *H. A.* viii. c. 5, s. 5. ‖ *Ibid.* viii. c. 14, s. 5. ¶ *Ibid.* viii. c. 18.

He states that the *Peristeroeide* usually lay two eggs, but *Phatta* and *Trygon* generally lay three.* This last statement is incorrect; there seems to be no record of birds of the pigeon family laying more than two eggs.

A small group of birds, the *Apodes* of Aristotle, so called because of their abnormally small or weak feet, includes *Chelidon* (the swallow), *Apous* or *Kypsellos* (the swift and house-martin), and *Drepanis* (the sand-martin).

Aristotle gives an important character of *Apous* or *Kypsellos*, *viz.*, that its metatarsus is feathered,† but he gives very little information about *Drepanis*, and Pliny and other ancient writers render no assistance in identifying this bird. The *Drepanis*, according to Aristotle, is closely allied to *Apous*, and is seen and caught when it rains in summer, but is a rare bird, on the whole.‡

Belon and Gesner identified *Drepanis* with the sand-martin, but, during comparatively recent years, there has been an inclination to identify it with the Alpine swift (*Cypselus melba*). This is not a good identification, and there does not seem to be sufficient reason to abandon Belon and Gesner's conclusion.

The name *Drepanis* (from *Drepane*, a sickle) does not give much assistance; it may refer to the shape of the wings, and would then favour the identification of *Drepanis* with the Alpine swift, or it may refer to the long, curved, hind claw of the sand-martin. It seems likely, however, that the Alpine swift, with its very short feet and feathered metatarsus, should be included with the common swift (*C. apus*), under the name *Apous*. Again, Aristotle's assertions about *Drepanis* do not appear to be consistent with the view that it is the Alpine swift, for this bird is very common in Greece, throughout the breeding season, and, according to Von der Mühle, is sold in large quantities in the Grecian markets.§

The sand-martin, which is somewhat rare in Greece, is said to breed in the banks of the Alpheus and the Eurotas, and to be seen in summer. It would be seen more especially after rains, and its stay in Greece is known to be comparatively short. All these considerations tend to show that *Drepanis* is the sand-martin. In his letter, previously referred to, Mr. G. C. Zervos expresses his opinion that

* *H. A.* vi. c. 4, s. 1. † *Ibid.* ix. c. 21, s. 1.

‡ *Ibid.* i. c. 1, s. 9.

§ Sharpe and Dresser's *Birds of Europe*, 1871–81, vol. 4. Section on *Cypselus melba*.

Drepanis was the name given by the ancient Greeks to the sand-martin.

The name *Kichle* is used by Aristotle for any kind of thrush. He says that the *Kichlai* build their nests in proximity to one another in tree tops, and that they make them of mud.* This description seems to apply best to the fieldfares, which nest in colonies, usually at a good height in trees, and, like some other thrushes, use mud in making their nests. He also says that there are three kinds of *Kichlai*, one of which, called *Ixoboros*, feeds on mistletoe and resin.† This bird is evidently intended to be the missel thrush. Aristotle says that *Ixoboros* is about as large as *Kitta*.‡ The common jay, which seems to be the *Kitta*, is somewhat larger than the missel thrush.

Aristotle says that there is a bird living among the rocks, especially in Scyros, and called *Kyanos*, or blue bird, that it is smaller than the *Kottyphos*, or blackbird, but larger than the *Spiza* (chaffinch?), that it is quite blue, and that its beak is long and smooth, its legs short, and its feet black.§

This description applies very well to the male blue rock thrush, which is common in Greece and, apparently, the Greek Isles.

Under the name *Aigithalos*, Aristotle included the tits, and says that they are insectivorous and lay more eggs than other birds.‖ There are, he says, three kinds, *viz.*, the *Spizites*, which is the largest and about as large as *Spiza* (apparently the chaffinch), the *Oreinos*, which lives in mountainous places and has a long tail, and a third which is very small.¶

Spizites and *Oreinos* are evidently the great tit (*Parus major*) and a long-tailed tit, *e.g.*, *Acredula caudata*, respectively. It is not possible to determine what the very small tit is intended to be; Sundevall identified it with the marsh tit (*Parus palustris*).**

Aristotle clearly refers to the nightingale, which he calls *Aedon*, the name which is still given to it by modern Greeks. The statements Aristotle makes about the nightingale, even about its song, are of but little importance, and his assertion that both the male and female sing †† is incorrect. This

* *H. A.* vi. c. 1, s. 3.
† *Ibid.* ix. c. 18, s. 2.
‡ *Ibid.*
§ *Ibid.* ix. c. 18, s. 3.
‖ *Ibid.* viii. c. 5, s. 3, ix. c. 16, s. 1.
¶ *Ibid.* viii. c. 5, s. 3.
** *Die Thierarten des Aristoteles*, 1863, p. 115.
†† *H. A.* iv. c. 9, s. 7.

error arose perhaps from the ancient popular belief about the origin of the nightingale, by the metamorphosis of an Athenian princess, Philomela, into a nightingale, or from failure to determine the sex of the singer. It is in Aristophanes that full justice is done to its song, the character representing the nightingale being called upon by the hoopoe, the king of the birds, to imitate the divine and entrancing notes of the nightingale by giving a flute solo.*

The *Epops*, according to Aristotle, lives in woody and mountainous regions,† and does not build a nest, but lays its eggs in a hollow tree.‡ This bird is the hoopoe. It frequents woods and open country which is not devoid of trees or bushes, but Aristotle's assertion that the *Epops* lives in mountainous regions seems to be quite true of the hoopoes of Turkey, for, in the Section on the Hoopoe, in vol. 5 of Sharpe and Dresser's *Birds of Europe*, the following statement by Mr. Robson of Ortakeuy is quoted:—"In Turkey, where the vernacular name signifies 'Mountain Cock,' they are most partial to the sides of mountains, although often found in the valleys."

The wryneck is sufficiently clearly indicated by Aristotle, who calls it *Iynx*, and says that it has dappled plumage, a long extensible tongue, and two toes directed forwards and two backwards, and that it hisses and turns its neck backwards, like a snake, while its body remains still.§ He also says that *Iynx* is a little larger than *Spiza*.‖ It is uncertain to what bird the name *Spiza* refers, but it is probable that a chaffinch is meant.

The insectivorous habits of the woodpecker, called by him *Dryokolaptes*, which means "one that makes holes in trees," are sufficiently clearly described by Aristotle, but he incorrectly states that its tongue is flat.¶ He refers to three kinds of woodpeckers, one of which may be the great black woodpecker (*Picus martius*); this kind, he says, is not much smaller than a domestic hen, and feeds on ants and larvæ.** A certain tame bird, he says, of this kind was known to place an almond in a chink in wood, and then break it at the third stroke of its bill, in order to get at the kernel.††

Aristotle's statements about the cuckoo are of much

* *The Birds*, 202–22.
† *H. A.* ix. c. 12, s. 3.
‡ *Ibid.* vi. c. 1, s. 3.
§ *Ibid.* ii. c. 8, s. 2; *P. A.* iv. c. 12, 695*a*.
‖ *Ibid.* ii. c. 8, s. 2.
¶ *Ibid.* ix. c. 10, s. 2.
** *Ibid.*
†† *Ibid.*

interest. He argues strongly against the opinion, which, he says, was held by some, that this bird was a kind of hawk.* The cuckoo (*Kokkyx*), he says, does not make a nest, but lays one or sometimes two eggs in the nest of some other bird, which hatches out and brings up its foster young.† He mentions the following foster-parents:—*Hypolais* (the hedge-sparrow, apparently), *Korydos* (the skylark), *Chloris* (the greenfinch, probably), and *Phaps*, which seems to be some kind of pigeon.

The hedge-sparrow is commonly and the skylark occasionally a foster-parent to the young of the cuckoo. Records of cuckoo's eggs being deposited in the nests of the greenfinch and the wood pigeon have also been made, according to Sharpe and Dresser.‡

Aristotle says that the cuckoo, when depositing its egg, devours the eggs of the foster-mother.§ This seems to be the only passage in which he expresses his own opinion on the fate of the eggs or young of the foster-mother. He also records the opinions of others on this subject. These opinions were: (1) that the young cuckoo ejects the young of the foster-parents; (2) that the foster-mother kills its own young; (3) that the old cuckoo re-visits the nest and kills the young of the foster-parents; (4) that the young cuckoo causes the death of the other young ones by appropriating all the food, and, (5) that the young cuckoo itself kills the other young ones.‖

It is clear, from (1) above, that, even as far back as the time of Aristotle, it was believed that the young cuckoo ejected the young of the foster-parents. Aristotle's own opinion is not altogether incorrect, for, according to Sharpe and Dresser,¶ the old cuckoo has been said to destroy the eggs of the foster-parents, when depositing its own egg. According to the same authorities, the old cuckoo has been known to revisit the nest and throw out the young of the foster-parents. This agrees with the ancient opinion (3) given above.

It is generally believed that the habit of cuckoos of entrusting the care of their eggs and young to other birds is largely due to the short period of their stay in the breeding-area not allowing them to hatch out and rear a sufficient

* *H. A.* vi. c. 7. † *Ibid.* vi. c. 7, ss. 2 and 3, ix. c. 20, s. 1.
‡ *Birds of Europe*, 1871–81, vol. 5. Section on *Cuculus canorus*.
§ *H. A.* vi. c. 7, s. 2. ‖ *Ibid.* ix. c. 20, ss. 1 and 2.
¶ *Op. cit.*

number of young ones. Aristotle's view on this question is quite different. He explains the habit by saying that cuckoos are very timid birds and cannot defend their young, but place them under the protection of other birds.*

He gives information about two birds, which he probably never saw, *viz.*, *Psittake* (the parrot) and *Strouthos Libykos* (the ostrich).

He says that *Psittake* is an Indian bird, which is said to have a tongue like that of a man, and that it talks most when intoxicated.†

The ostrich, he says, has some of the characters of a bird, *e.g.*, it has wings, feathers, and two legs, and some of the characters of a quadruped, *e.g.*, it has cloven feet with hoofs, "hair-like feathers" which are useless for flight, and upper eyelashes.‡

Pliny calls the ostrich *Struthio-camelus*, and a popular belief in the "bird-quadruped" nature of the ostrich has been very persistent, and is said to exist in Arabia. The ostrich has two toes on each foot, an inner very large one with lateral expansions and a nail, quite unlike a hoof, and an outer small toe which is often without a nail. It has both upper and lower eyelashes, composed of hair-like feathers.

Aristotle also states that the ostrich lays many eggs,§ and does not seem to have known that several hens lay in one nest.

* *H. A.* ix. c. 20, s. 3. † *Ibid.* viii. c. 14, s. 6.
‡ *P. A.* iv. c. 13, 697*b*. § *H. A.* ix. c. 16, s. 1; *G. A.* iii. c. 1, 749*b*.

CHAPTER XVIII.

ARISTOTLE'S ENAIMA, OR ANIMALS WITH BLOOD (*continued*).

The best-defined group of Aristotle's *Enaima* is his *Kete* or *Ketode*. He says that they are truly viviparous, that they have mammæ and furnish milk, and that they have lungs and a blowhole.* The fish-like forms of these animals, and their habit of coming to the surface of the sea to spout were known to him,† but he states erroneously that they turn on their backs to take their prey, because their mouths, like those of his *Selache*, are on their ventral sides.‡

By his researches on his *Kete* or *Ketode*, Aristotle achieved an important result, for he clearly distinguished them from fishes and from other viviparous animals. The word *Kete* had been used by Homer, Arrian, and other writers to denote very large aquatic animals, but Aristotle clearly uses it and also *Ketode* to denote a distinct group. He fully deserves the praise accorded by Sir Richard Owen, who says:—"The apodal *Vivipara*, which form the third of Aristotle's more comprehensive groups, embraces the *Ketode*, now called *Cetacea*, and affords, by its position and co-ordinates in the great philosopher's zoological system, one of the most striking examples of his sagacity and research."§

The *Kete* or *Ketode* mentioned by Aristotle are *Delphis*, *Phalaina*, *Mystiketos*, and *Phokaina*. In the numerous passages relating to *Delphis*, or the dolphin, he refers particularly to its well-known carnivorous habits, sportiveness, swiftness, and attentiveness to its young. He says also that, when it comes to the surface, it squeaks and makes a murmuring noise.‖ The latter part of this statement is correct, for it is known that the dolphin makes a murmuring noise.

* *H. A.* i. c. 4, s. 1, iii. c. 16, s. 1.
† *H. A.* viii. c. 2, s. 3; *P. A.* iv. c. 13, 697*a*; *De Respir.* c. 12, 476*b*.
‡ *H. A.* viii. c. 4, s. 4.
§ *Classific. and Geogr. Distrib. of the Mammalia, &c.*, 1859, p. 3.
‖ *H. A.* iv. c. 9, s. 4.

Aristotle says that the blowhole of *Delphis* is διὰ τοῦ νώτου, or through its back.* It is practically certain that he is referring to the dolphin, although its blowhole is as nearly as possible on the same transverse periphery as its eyes. In other passages, he states correctly that its blowhole is in front of its brain.†

According to Aristotle, the dolphin brings forth one young one, or sometimes two, always in the summer season, the period of gestation being ten months; he also says that dolphins have been known to live from twenty-five to thirty years, fishermen having ascertained this by cutting the dolphins' tails and then allowing them to escape.‡

These are interesting statements. About the ages of dolphins I have no information. With respect to its breeding habits, it is well known that the common dolphin brings forth one young one at a birth. I cannot find a clear statement about the period of gestation of the common dolphin, but Millais states, on the authority of Nansen and Guldberg, that the period for the white-sided dolphin is ten months, and that the young one is born before or about midsummer.§

It is difficult to identify Aristotle's *Phalaina*, for he does not give any information about its size or geographical distribution, and, apart from information which shows that it is a cetacean, merely states that its blowhole is in its forehead, and that it usually brings forth two young ones, but sometimes only one.‖

It might seem to be reasonable to assume that Aristotle's *Phalaina* is a whale, such as *Balænoptera musculus*, the common or Mediterranean rorqual, which often brings forth two young ones at a birth. It is more probable, however, that the *Phalaina* is one of the larger dolphins, *e.g.*, the killer, Risso's grampus, or the blackfish, for the rorqual is a whalebone whale, and Aristotle seems to use another name, *Mystiketos*, for a whale of this kind. In the only passage in which he refers to *Mystiketos*, he states clearly that it has no teeth in its mouth, but hairs like boars' bristles.¶

The *Phalainai* graphically described by Arrian and Strabo, and the *Ballænæ* of Pliny, were undoubtedly large

* *H. A.* i. c. 4, s. 1.
† *P. A.* iv. c. 13, 697*a*; *De Respir.* c. 12, 476*b*.
‡ *H. A.* vi. c. 11, ss. 1 and 2.
§ *Mammals of Great Britain, &c.*, vol. iii. 1906, p 339.
‖ *H. A.* i. c. 4, s. 1, vi. c. 11, s. 1. ¶ *Ibid.* iii. c. 10, s. 13.

whales, those described by Arrian, in particular, being the whales seen during the voyage of Nearchus from the Indus to the Persian Gulf. Two years elapsed between the time of that voyage and the death of Aristotle, but there is nothing to show that he knew anything of the whales seen by Nearchus.

Aristotle's *Phokaina* is the porpoise (*Phocæna communis*), for he says that it is smaller than the dolphin, but relatively wider across the back; he also says that it is like a small dolphin, and that some considered it to be a kind of dolphin.*

The viviparous animals with feet form a group which corresponds with the Mammalia, other than the Cetacea. Their chief characteristics are, according to Aristotle, that they are truly viviparous, that they have hairs, that they have mammæ and furnish milk, and that they not only have lungs, but also an epiglottis.†

The number of species referred to by Aristotle cannot be determined. Not less than sixty-six names are mentioned by him, but it is certain that he sometimes applies more than one name to one and the same animal, *e.g.*, he calls the beaver by the names *Latax* and *Kastor*, and, possibly, *Satyrion* and *Satherion* also. It is also certain that some of the names he employs refer to more than one species or even genus of animals, *e.g.*, his *Kamelos* includes both *Camelus dromedarius* and *C. bactrianus*, his *Kebos* includes more than one genus of monkeys, and his *Nykteris* more than one genus of bats.

Among his viviparous animals with feet, the *Non-Amphodonta* is a fairly well-defined group, and corresponds, as far as it goes, with the *Ruminantia* of modern classifications. Their distinguishing feature, according to Aristotle, is the absence of front teeth in the upper jaws, but he erroneously included the camel, which has incisors in the upper jaws, as explained in Chapter x. The chief animals included by Aristotle among the *Non-Amphodonta* seem to be the following:—oxen of various kinds (*Tauros*, *Bous*); bison (*Bonassos*); sheep of various kinds (*Ois*, *Krios*, *Probaton*); goats of various kinds (*Tragos*, *Aix*, *Chimaira*); oryx (*Oryx*); deer of various kinds (*Elaphos*, *Prox*); nilgai (*Hippelaphos*); camel (*Kamelos*); gazelle (*Dorkas*), and the *Pardion*.

* *H. A.* vi. c. 11, s. 1.

† *H. A.* i. c. 4, s. 1, iii. c. 10, s. 1, iii. c. 16, s. 1; *G. A.* ii. c. 4, 737*b*; *P. A.* iii. c. 3, 664*b*.

In numerous passages relating to oxen, sheep, and goats, he describes various breeds, their food, diseases, and habits. He records the existence of the well-known flat-tailed sheep of western Asia, for he says that, in Syria, there are sheep with tails a cubit in width.* The goats of Syria, he says, have ears about a foot long, and, in some cases, their ears hang to the ground; the goats of Lycia, he adds, are shorn just as sheep are in other places.† Aristotle is evidently referring to the well-known Syrian goat, which has exceptionally long ears, and his Lycian goat is probably the well-known Angora goat.

In a long description of *Bonassos*, Aristotle makes it clear that it was a wild, ox-like animal, heavily built, with horns nearly nine inches long and turned towards each other, that it had a mane from its head to its shoulders, and a thick mass of hair extending as far as its eyes, in such a way that it could see better sideways than in front, that its colour was between ash colour and red or tawny, and that it was found in Pæonia.‡ This animal was evidently the European bison.

Aristotle says that there are no deer in any part of Libya.§ This is not true. South of the Sahara, no deer are said to be found, but, in northern Africa, there are deer, *e.g.*, the fallow deer and the Barbary deer. Aristotle seems to have copied a precisely equivalent statement from Herodotus.‖

In Chapter x. some of Aristotle's statements about the horns of *Elaphos*, the red deer in particular being meant, have been discussed.

The *Hippelaphos* has been much discussed by naturalists, and some have attempted to discover it in territories as far apart as Bengal and South Africa. According to Aristotle, it was found in Arachosia, was cloven-footed, and furnished with a tuft of hair on its throat, and also had a mane; the female was hornless, but the male had horns like those of the *Dorkas*, or gazelle.¶

Pallas tried to identify this animal with Pliny's *Tragelaphos*, an animal living near the river Phasis.** According to Desmarest,†† Allamand attempted to identify it with the gnu of South Africa; it may be mentioned that Allamand was

* *H. A.* viii. c. 27, s. 3.
† *Ibid.* viii. c. 27, s. 3.
‡ *Ibid.* ix. c. 32.
§ *Ibid.* viii. c. 27, s. 3.
‖ iv. 192.
¶ *H. A.* ii. c. 2, ss. 3 and 4.
** *Spicilegia Zoolog. Fasciculus Undecimus*, 1776, p. 51.
†† *Mammalogie*, 1822, 2nd part, p. 472.

one of the first, if not the first, to give a reliable description of the gnu. Cuvier attempted to identify the *Hippelaphos* with the sambhur or black rusa of Bengal, called by him *Cervus Aristotelis*.*

Probably this animal was unknown to Aristotle, and, in other respects, the identification is unsatisfactory, *e.g.*, Aristotle says that the horns of *Hippelaphos* are like those of *Dorkas*. Now, the horns of *Dorkas*, or the gazelle, are unbranched, but the sambhur has branched horns. Again, the erectile ridges of hair, on the throats of the few male sambhurs I have been able to inspect, were not very conspicuous.

Wiegmann's suggestion that *Hippelaphos* is the nilgai (*Antilope picta*, Pallas) † seems to give the best identification. The nilgai, called by sportsmen the blue bull, has a mane, and a very conspicuous tuft of black hair on its throat. Its horns are similar in colour, size, and general form to those of many gazelles. On closer comparison, the resemblance fails, for the horns of the nilgai are fairly smooth, and their basal parts are nearly triangular in cross-section, while the horns of the gazelle are more or less oval in cross-section, and are corrugated transversely. However, Aristotle's comparison, if not taken too strictly, applies to these animals. Further, the female nilgai, like the female *Hippelaphos*, is hornless.

Finally, the nilgai occurs chiefly in central and northern India, its habitat extending towards, though, apparently, not including, Arachosia, where the *Hippelaphos* was found.

The only information given by Aristotle about *Dorkas* is that its horns and those of *Hippelaphos* are similar,‡ and that it was the smallest horned animal with which he was acquainted.§

Aristotle's *Dorkas*, like the *Dorkas* of Xenophon and Ælian, was a gazelle. Some gazelles, *e.g.*, the Arabian gazelle and the Dorcas gazelle, are small, but horned animals much smaller than these are now known, such as, for instance, the royal antelope (*Neotragus pygmæus*), of the Gold Coast, which is about ten inches high at the shoulders.

The well-known belief in the existence of a unicorn is very ancient and widespread. The Kylin of China, Aristotle's *Oryx*, and so called "Indian ass," to be referred to again

* *Le Règn. Anim.* 1836–7, volume on "Mammals," p. 308.
† *Observ. Zool. Critic.* 1826, p. 26. ‡ *H. A.* ii. c. 2, s. 4.
§ *P. A.* iii. c. 2, 663*b*.

later, and the mythical unicorn shown on coats-of-arms, are representative of such an animal. The *Oryx*, according to Aristotle, has a single horn in the middle of its head, and is cloven-footed.* Pliny, probably referring to the same animal, says that its hair is directed towards its head. †

It is probable that the *Oryx* is the Beisa (*Oryx beisa*), or the sabre-horned antelope (*O. leucoryx*). That Aristotle saw either of these animals is unlikely, and he probably relied on descriptions which brought out in relief the remarkable one-horned appearance of these animals, when seen sideways. Sundevall says that the *Oryx* is sometimes shown on Egyptian sculptures and paintings, so that the two horns appear as one.‡ I have met with but small success in finding such representations. In the *Memoirs of the Archæological Survey of Egypt*, 1893–1900, there are several representations of one-horned animals, a few of which seem to be *Oryxes*, but these animals are more commonly shown with two horns. A very good representation of *Oryxes*, with both horns shown, may be seen, *e.g.*, in the painting called "The Farmyard: Feeding the Oryxes."§

It may be mentioned that Oppian of Syria gives a long and interesting description of the *Oryx*.‖ On the whole, his description applies best to *Oryx leucoryx*.

In addition to information about the longevity, food, diseases, and mode of life of camels, Aristotle says that the Arabian camel brings forth but one foal at a birth, and that the period of gestation is twelve months.¶ The first statement is quite correct, and the second very nearly so, the period of gestation being a little more than twelve months. In another passage, he states more erroneously that the period of gestation is ten months.**

Aristotle says that the *Pardion* or *Hippardion* is a cloven-footed wild animal having a mane and horns.†† In Schneider's Greek text, the animal is called *Pardion*, but, in the texts of Syllburg, Scaliger, and Camus, it is called *Hippardion*. It may be the giraffe, as Pallas, Sundevall, and others believed, for Aristotle may have been acquainted with it, by report at least, although it was not well known

* *H. A.* ii. c. 2, s. 9; *P. A.* iii. c. 2, 663*a*.
† *Nat. Hist.* viii. 79.
‡ *Die Thierarten des Aristoteles*, 1863, p. 64.
§ *Beni Hasan*, part 1, plate xxvii. Published by the Arch. Survey of Egypt, London, 1893.
‖ *Cynegetica*, ii. 445–88. ¶ *H. A.* v. c. 12, s. 13.
** *Ibid.* vi. c. 25, s. 1. †† *Ibid.* ii. c. 2, s 3.

to the Ancients. Pliny describes it under the names *Nabun* and *Camelopardalis*, and says that it was first seen at Rome during Cæsar's dictatorship.*

The *Monycha* described by Aristotle are the horse (*Hippos*), the ass (*Onos*), the wild ass (*Onos agrios*), the so-called Indian ass (*Onos Indikos*), the Syrian half-ass (*Hemionos*), the mule (*Oreus*), the hinny (*Hinnos*), the ginny (*Ginnos*), and the pigs of Illyria and Pæonia, in which syndactylism occurred, as explained already in Chapter x.

The so called Indian ass was, according to Aristotle, solid-footed and one-horned, and the only animal with solid hoofs and also a well-formed astragalus.† This animal, the description of which was probably taken from Ctesias, was a creature of the imagination. Some antelopes, when seen sideways, appear to have one horn, and this was probably the basis of reports about the Indian ass, communicated to Ctesias by visitors from India to the Persian Court, where he resided. It is unlikely that the Indian ass was an Indian rhinoceros, as some have suggested. Not only does a rhinoceros answer very imperfectly to the descriptions, based on Ctesias, of the Indian ass, but it is probable that Ctesias did not know anything of rhinoceroses, for it seems, from what Ælian says, that a rhinoceros was first reported, from Æthiopia, by Agatharchides, who lived about B.C. 100.‡

The horse and other equine animals mentioned above form one of Aristotle's best-defined groups, the *Lophoura*, distinguished by having a small cranium but long jaws, and a mane and tail of long flowing hair.§

Aristotle gives a great deal of information about these animals, but much of it is of little interest. There are, however, in addition to anatomical information already dealt with, chiefly in Chapter x., many passages relating to the sterility and fertility of equine hybrids. The *Ginnos*, he says, is the offspring of a mule and a mare, but no female mule has been known to have offspring.‖ In *G. A.* ii. c. 7, 746*b*, he goes further than this, and says that mules (*Oreis*) are incapable of generating, either among themselves or with other animals, and adds that the whole group of *Hemionoi* is sterile. The word *Hemionoi* in this passage seems to be used for mules and like hybrids generally, for he distinctly asserts¶ that the *Hemionoi* of Syria are fertile.

* *Nat. Hist.* viii. 27.
† *H. A.* ii. c. 2, s. 9.
‡ *De Nat. Anim.* v. 27.
§ *H. A.* i. c. 6, s. 3, i. c. 13, s. 3.
‖ *Ibid.* vi. c. 24, s. 1.
¶ *Ibid.* i. c. 6, s. 3, vi. c. 24, s. 1.

No well-authenticated instances of mules or other hybrids of the equine family breeding among themselves seem to have been recorded, but the female mule has been known to breed with the horse and the ass. The Ancients strongly believed in the sterility of mules, and it is related by Herodotus that one of the Babylonians expressed surprise at the Persians continuing the siege of Babylon, saying that they would have to wait till mules brought forth young, but, adds Herodotus, in the twentieth month, one of the baggage mules of Zopyrus did bring forth a foal.*

Aristotle speaks of the wild ass and also the half ass of Syria (*Hemionos*), but it is probable that these are asses of one and the same species, the wild ass of western Asia (*Equus hemionus*).

The remaining viviparous animals with feet, which Aristotle preferred to describe singly, are given in the following tables, the first of which includes those animals which can be identified satisfactorily, and the second those about the identity of which there is much uncertainty. In a few instances more than one name is used for the same animal.

TABLE I.

Ailouros (Cat)
Alopex (Fox)
Arktos (Bear)
Aspalax (Mole)
Dasypous (Hare)
Echinos (Hedgehog)
Eleios (Dormouse)
Elephas (Elephant)
Enydris (Otter)
Gale (Beech Marten)
Glanos (Hyæna)
Hippos-potamios (Hippopotamus)
Hyaina (Hyæna)
Hys (Pig)
Hystrix (Porcupine)
Ichneumon (Mongoose)
Kapros (Boar)
Kastor (Beaver)
Kebos (Monkey, tailed)
Kuon (Dog)
Kynocephalos (Baboon)
Lagos (Hare)
Latax (Beaver)
Leon (Lion)
Lukos (Wolf)
Lynx (Lynx)
Mus (Mouse)
Nykteris (Bat)
Panther (Leopard)
Pardalis (Leopard)
Phoke (Seal)
Pithekos (Barbary Ape)
Thos (Jackal)

TABLE II.

Alopex (Fox-Bat)
Choiropithekos (Drill)
Iktis (Weasel)
Mantichora (Bengal Tiger)
Mygale (Shrew-mouse)
Satherion (Beaver)
Satyrion (Beaver)
Tigris (Tiger)

* iii. 151–3.

The statements made by Aristotle about some of these animals will be considered.

Aristotle's *Gale* and *Iktis* are closely related, for he says that *Iktis* is like *Gale* in the thickness of its fur, in its appearance, in the whiteness of its under parts, and in its cunning disposition; he also says that it is easily tamed, very fond of honey, is about as large as a small Maltese dog, and that it eats birds like a cat.* He also says that the *Gale* kills birds by lacerating their throats, just as a wolf kills sheep, and that it attacks snakes, especially those which, like itself, hunt mice.†

There are many references in the ancient writers, *e.g.*, Aristophanes, from which it is clear that *Gale* was a domestic animal. Prof. Rolleston concluded that *Gale* was the beech marten (*Mustela foina*), and *Iktis* the pine marten (*M. martes*).‡ The chief object of his paper is to show that the *Gale* performed for the ancient Greeks the same duties as are performed for us by the domestic cat, and this object is effected so successfully as to leave no doubt in the mind of a reader of the paper. Prof. Rolleston's identification of *Iktis* is less satisfactory.

Cetti, in *I Quadr. di Sardegna*, 1774, p. 179, and Sundevall, in *Die Thierarten des Aristoteles*, 1863, p. 49, held that the boccamele or Sardinian weasel (*M. boccamele*), discovered by Cetti, about the year 1770, was Aristotle's *Iktis*. It kills birds, mice, and other small animals, and is said to be easily tamed. The specimens of this animal which I have seen at the Natural History Museum, South Kensington, are larger than the common weasel and darker in colour. Respecting Aristotle's statement that *Iktis* is fond of honey, it is said that the name "boccamele" was given to the Sardinian weasel because of its fondness for honey, but conclusive evidence about this is not readily obtainable. Mr. G. C. Zervos, of Calymnos, informs me that he does not know of any weasel of the Greek area notoriously fond of honey.

In conclusion, the boccamele and the beech marten seem to furnish the best identifications of *Iktis* and *Gale*, respectively. According to Mr. G. C. Zervos, modern Greeks regard *Gale* as the "cat" of the ancient Greeks, and *Iktis*

* *H. A.* ix. c. 7, s. 5. † *Ibid.* ix. c. 7, s. 4.

‡ "On the Domestic Cats, *Felis domestica* and *Mustela foina*, of Ancient and Modern Times," *Science Papers, &c.*, 1884, 2 vols., Paper 28.

as the same animal as the modern Greek *Nyphitsa*, which is a weasel or ferret.

Aristotle credits the lion with much magnanimity and courage; he says, however, that there are two kinds of lions, that one of these is not so courageous as the other, and that an infuriated boar has been known to put a lion to flight.* Like several modern writers, he does not seem to have believed that the lion was undoubtedly bold and fierce.

He asserts that, in his time, lions were found in Europe, but only in the territory between the rivers Achelous and Nessus.† Herodotus also mentions the existence of lions between the Achelous and Nessus.‡ There are several other passages in the ancient authors tending to show that lions lived in southern Europe in historic times, but it is not known when they became extinct there.

The *Martichora*, called *Mantichora* in some texts, is described by Aristotle on the authority of Ctesias. According to this description, it was a wild, fleet animal living in India and eating human flesh; it had feet like those of a lion, and was as large as that animal; its body was red, and its eyes were blue; its tail was like that of a scorpion and bristled with spines; and, in each jaw, there were three rows of teeth.§

According to Ælian, Ctesias says that he once saw a *Martichora* which had been sent from India as a present to the King of Persia.‖ It may be added, in justice to Ælian, that he properly questions whether Ctesias was a fitting witness to things of this kind. The *Martichora* was largely a creature of the imagination. Sundevall fancied he saw, in Ctesias' description, the outlines of some fantastic and badly executed image or painting, representing a strange being of Hindu mythology.¶ Gesner describes it in a passage between his description of the hyæna and the porcupine, and preferred to believe that it was not a tiger.** Pausanias believed that it was a tiger,†† and it is probable that the description, given by Ctesias, is a distorted account of a Bengal tiger, an animal regarded with almost superstitious dread by the Hindus.

The *Enydris* or otter, according to Aristotle, obtains its

* *H. A.* ix. c. 31, s. 3.
† *Ibid.* vi. c. 28, s. 1, viii. c. 27, s. 6.
‡ vii. 126.
§ *H. A.* ii. c. 3, s. 10.
‖ *De Nat. Anim.* iv. 21.
¶ *Die Thierarten des Aristoteles*, 1863, p. 90.
** *Hist. Anim.* i. 1551, p. 631.
†† *Desc. of Greece*, ix. 21, 4.

food in or about ponds and rivers, and it also bites men and, from information given to him, does not let go until it hears the crunching of the bone.* Pliny, in a passage taken to some extent from Aristotle, seems to refer, by the name *Lutra*, to the same animal as Aristotle's *Enydris*.† It should be mentioned, however, that Pliny, when repeating the part of Aristotle's statement about the hard biting, applies it not to *Lutra* but to the beaver. The statement would apply to either, for both the beaver and the otter bite very hard.

Among wild animals which obtain their food in or about lakes and rivers Aristotle mentions *Latax*, which goes out by night and cuts the aspens with its strong teeth; he also says that its body is broader than that of *Enydris*, and that its hair is harsh, being intermediate between that of a deer and that of a seal.‡ This is the only important passage, mentioning *Latax*, which I can find, but it contains sufficient information to show that, probably, the beaver is meant. The reference to the aspens is important, for the bark of these trees is said to be the favourite food of the beaver.

The elephant is referred to by Aristotle in many passages, some of which have been discussed in Chapters x., xi., and xiii. The question of the period of gestation, in the case of the elephant, does not seem to have been settled in Aristotle's time, for he says that, according to some people, it is eighteen months, but, according to others, it is as much as three years.§ Aristotle does not give his own view, but the first-mentioned estimate is substantially true, the normal period for the Indian elephant being nineteen months.

Aristotle says that the elephant throws over or tilts palm trees with its forehead, and then tramples upon them and throws them down,‖ but, in another passage, he says that it uproots trees by means of its trunk.¶ By means of their trunks elephants can uproot small trees, but several writers, like Sir J. Emerson Tennent and Mr. G. P. Sanderson, agree that elephants are by no means in the habit of trying their strength in this way. The trunk of an elephant is very sensitive, and it is well known how carefully the animal usually protects it from injury. The African elephant "Alice" once met with an accident involving the tearing away of the extremity of her trunk and the *late* Superintendent of the London Zoological Gardens, Mr. A. D.

* *H. A.* viii. c. 7, s. 5.
† *Nat. Hist.* viii. 47.
‡ *H. A.* viii. c. 7, s. 5.
§ *Ibid.* vi. c. 25, s. 2.
‖ *Ibid.* ix. c. 2, s. 11.
¶ *Ibid.* ii. c. 1, s. 2.

Bartlett, described in graphic terms the intense distress of the poor animal.* Aristotle was not aware how delicate is the trunk of an elephant.

An erroneous belief in the capability of elephants to perform great feats of strength with their trunks is easily produced, and such a belief is very persistent. About the year 1873 a large elephant, when passing through a village near Dudley, broke down a cast-iron lamp-post. It was long believed, and may still be believed by some, that the elephant did this with its trunk. The few persons who saw what actually took place know, however, that the animal wilfully pressed against the post with its shoulder.

The *Pithekos*, *Kebos*, and *Kynocephalos* which, Aristotle says, are of the nature of men and quadrupeds, are sufficiently clearly distinguished by him. The *Pithekos*, according to him, is without a tail, the *Kebos* has a tail, and the *Kynocephalos* is fierce, larger and stronger than *Pithekos*, and has stronger teeth, and its face is more like that of a dog.† He gives but little further information about *Kynocephalos* and *Kebos*, but gives a fairly long account of *Pithekos*. He refers to the almost human appearance of its face, teeth, fingers, and nails, its pectoral mammæ, its comparatively short humerus and femur, and its habit of spending most of its time on all fours.‡

Aristotle's *Kynocephalos* is evidently a baboon, the Arabian or sacred baboon being the one with which he would be more likely to be acquainted, his *Kebos* is a tailed monkey (but to what kind he particularly refers is not clear), and his *Pithekos* is the Barbary ape. This animal would be more likely to be known by the Ancients than the gorilla and chimpanzee, yet it was long believed that they obtained a knowledge of some kind of anthropoid ape from the Carthaginians, for it is said that Hanno, during his celebrated voyage in the fifth century B.C., saw some animals of this kind on the extreme west coast of Africa.

Not only does Aristotle's description of *Pithekos* apply better to the Barbary ape, but there are passages, *e.g.*, that asserting that the chest of every animal but Man is narrow,§ which could scarcely have been written by Aristotle if he had been acquainted with the anthropoid apes. Further, with respect to other ancient writers, many passages in

* *Wild Animals in Captivity*, 1899, pp. 51–53.
† *H. A.* ii. c. 5, s. 1. ‡ *Ibid.* ii. c. 5, ss. 2–5.
§ *Ibid.* ii. c. 1, s. 3.

their works seem to show that these apes were not known to them. The *Pithekos*, in Æsop's fable, "The *Pithekos* and the Dolphin," was evidently a monkey, Arrian's beautiful Indian *Pithekoi*,* Ælian's Indian *Pithekos*, with a long tail,† the clever *Pithekos* which he once saw holding the reins and, at the same time, using a whip and driving,‡ and the *Pithekoi* which were pursued by cats and forced to ascend trees from which they hung down by means of their hands,§ were monkeys. Finally, Galen, who had great difficulty in obtaining human bodies for dissection, often dissected a *Pithekos* instead, and it is clear from his writings that this was a Barbary ape.

This account of Aristotle's investigations of animals will conclude with a short statement of his views on Man.

Man is, for him, always ζῷον, a living being, an animal, but he is the highest representative of the whole series of living beings. He is distinguished from other animals by having a perception of good and evil, justice and injustice, and the like,‖ and by his capability of deliberating and of recalling anything to mind.¶ Many animals, Aristotle says, are able to remember, but Man alone is capable of reminiscence, this involving a process of syllogistic reasoning.** Aristotle is very severe in his judgment on some types of men, for he says that those who are not amenable to law and justice are among the worst, and, if devoid of virtue, are the most unholy, savage, and gluttonous animals, while those who are highly cultured are the best and noblest.††

This discussion of Aristotle's researches in Natural Science shows how vast was the field of knowledge which he attempted to traverse. It is not pretended that the discussion is comprehensive. Much that Aristotle included in his voluminous writings has been omitted. That which has been included has been selected with a view to showing fairly the defects of Aristotle's work as well as its excellences. Care has been taken to show that his writings contain statements which he could never have attempted to verify, and that he sometimes gave an explanation of phenomena which was based on false data, obtained by

* *Hist. Indica*, c. 15.
‡ *Ibid.* v. 26.
‖ *Poltics*, i. c. 1, ss. 10–11.
** *De Memoria, &c.*, c. 2.
† *De Nat. Anim.* xvii. 39.
§ *Ibid.* v. 7.
¶ *H. A.* i. c. 1, s. 15.
†† *Politics*, i. c. 1, s. 13.

abstract reasoning, and not from facts previously ascertained. On the other hand, prominence has been given to his excellent method of inquiry, his interesting views on the phenomena of light, colour, and heat, his records of comets, earthquakes, volcanic eruptions, and relative changes in the distribution of land and sea, his views on the constitution of matter, his attempt to form a classification of animals, his advice on the importance of dissection, the instances in which he appears to have anticipated modern discoveries, and his excellent work in anatomy, embryology, and zoology.

If the reader is satisfied that an impartial attempt has been made to set out the real nature and value of Aristotle's work in Natural Science, this book will have achieved its object.

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English names of animals are followed, in most cases, by the Aristotelian names apparently equivalent, *e.g.* Alpine swift (*Apous*). Separate entries are also made for Aristotelian names of animals of special interest, *e.g. Aspalax*, *Glanis*, *Skaros*.

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